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Evolutionary Acquisition

Implementation Challenges for Defense Space Programs

Mark A. Lorell, Julia F. Lowell, Obaid Younossi

Prepared for the
United States Air Force

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Preface

This monograph is one of a series from a RAND Project AIR FORCE (PAF) project, "The Cost of Future Military Aircraft: Historical Cost Estimating Relationships and Cost Reduction Initiatives." The purpose of the project is to improve the tools used to estimate the costs of future weapon systems. It focuses on how recent technical, management, and government policy changes affect cost. This document reports research findings on lessons learned relevant to the Department of Defense (DoD) cost estimating and system acquisition management community related to implementing evolutionary acquisition (EA) strategies in major defense space acquisition programs. EA strategies are major acquisition reform measures that were formalized as the "preferred approach" to weapon system acquisition under the first Bush administration's DoD leadership. While these strategies aim at enhancing the outcomes of all aspects of the acquisition process, their single most important objective is to reduce dramatically the time between the identification of new operational needs and the fielding of operationally useful equipment to begin to meet those needs.

The core concept of EA strategies is to acquire new capabilities in multiple, shorter-phased spirals or increments. In principle, the initial spirals or increments provide a basic "threshold" capability relatively quickly, which is operationally useful. Subsequent spirals or increments build on this to provide more capability, eventually resulting in a system that meets the full "objective" capability originally envisioned at the beginning of the program. This approach contrasts

with the traditional acquisition strategy of focusing on a single step to full objective capability, an approach that critics claim often results in inordinately long developmental schedules that produce no useful operational capability for many years, and that often lead to serious problems with schedule slippage and cost growth. Thus, EA strategies are intended to increase the efficiency of DoD's acquisition process and result in the rapid fielding of useful new capabilities. This research aims to examine some of the implications of the EA strategy for the cost estimating and acquisition management community.

These research findings are based on extensive structured interviews with government cost analysts, contracting officers, and other senior acquisition officials representing the Office of the Secretary of Defense (OSD) and the Office of the Secretary of the Air Force (SAF). For more detailed lessons learned in implementing EA strategies, the authors interviewed the relevant officials from several program offices at the U.S. Air Force Space and Missile Systems Center (SMC) and the DoD Missile Defense Agency (MDA).[1]

This monograph should be of interest to cost analysts, contracting officers, acquisition policymakers, and other senior acquisition officials interested in acquisition reform and new approaches to contracting and incentivizing contractors to achieve the best value in defense procurement.

Other RAND Project AIR FORCE documents that address military aircraft and other cost estimating issues include these:

- In *An Overview of Acquisition Reform Cost Savings Estimates*, MR-1329-AF, Mark A. Lorell and John C. Graser used relevant literature and interviews to determine whether estimates of the efficacy of acquisition reform measures are robust enough to be of predictive value.
- In *Military Airframe Acquisition Costs: The Effects of Lean Manufacturing*, MR-1325-AF, Cynthia R. Cook and John C. Graser examine the package of new tools and techniques known

[1] See Chapter One for organizations represented by interviewees.

as "lean production" to determine whether it would enable aircraft manufacturers to produce new weapon systems at costs below those predicted by historical cost estimating models.

- In *Military Airframe Costs: The Effects of Advanced Materials and Manufacturing Processes*, MR-1370-AF, Obaid Younossi, Michael Kennedy, and John C. Graser examine cost estimating methodologies and focus on military airframe materials and manufacturing processes. This monograph provides cost estimators with factors useful in adjusting and creating estimates based on parametric cost estimating methods.
- In *Military Jet Engine Acquisition: Technology Basics and Cost-Estimating Methodology*, MR-1596-AF, Obaid Younossi, Mark V. Arena, Richard M. Moore, Mark A. Lorell, Joanna Mason, and John C. Graser present a new methodology for estimating military jet engine costs and discuss the technical parameters that derive the engine development schedule, development cost, and production costs, and present quantitative analysis of historical data on engine development schedule and cost.
- In *Test and Evaluation Trends and Costs in Aircraft and Guided Weapons*, MG-109-AF, Bernard Fox, Michael Boito, John C. Graser, and Obaid Younossi examine the effects of changes in the test and evaluation (T&E) process used to evaluate military aircraft and air-launched guided weapons during their development programs.
- In *Software Cost Estimation and Sizing Methods: Issues, and Guidelines*, MG-269-AF, Shari Lawrence Pfleeger, Felicia Wu, and Rosalind Lewis recommend an approach to improve the utility of the software cost estimates by exposing uncertainty and reducing risks associated with developing the estimates.
- In *Lessons Learned from the F/A-22 and F/A-18 E/F Development Programs*, MG-276-AF, Obaid Younossi, David E. Stem, Mark A. Lorell, and Frances M. Lussier evaluate historical cost, schedule, and technical information from development of the F/A-22 and F/A-18 E/F programs to derive lessons for the Air Force and other services to improve the acquisition of future systems.

The research reported here was sponsored by Lieutenant General John D. W. Corley, Principal Deputy Assistant Secretary of the Air Force for Acquisition (SAF/AQ), and conducted within the Resource Management Program of RAND Project AIR FORCE. The point of technical contact was Mr. Jay Jordan, Technical Director, Air Force Cost Analysis Agency (AFCAA/TD).

RAND Project AIR FORCE

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Summary

Introduction and Research Approach

This monograph presents findings of a RAND Project AIR FORCE research project that documented the lessons learned by the U.S. Air Force and other Department of Defense (DoD) cost analysis and acquisition community members from the implementation of evolutionary acquisition (EA) strategies for major Air Force defense space acquisition programs. In May 2003, DoD promulgated revised 5000 series acquisition directives and instructions that mandated EA strategies relying on the spiral development process as the preferred approach to satisfying operational needs.[1] These same concepts were later incorporated into a new space acquisition policy document, the National Security Space Acquisition Policy (NSSAP) 03-01 (DoD, 2004).

The principal goal of EA strategies is to provide operationally useful capabilities to the warfighter much more quickly than traditional acquisition strategies. Instead of the old approach of "single step to full capability," evolutionary acquisition aims at achieving an overall objective end capability through the more rapid fielding of numerous operationally useful threshold capabilities by pursuing less demanding intermediary increments or steps. In theory, the initial spirals or increments provide a basic "threshold" capability relatively

[1] The DoD 5000 acquisition policy guidance documents have been the key DoD publications establishing the basic process and structure for developing and procuring U.S. weapon systems since July 1971 (Ferrara, 1996).

quickly, which is operationally useful to the user. Subsequent spirals or increments build on this to provide more capability, eventually resulting in a system that meets the full "objective" capability originally envisioned at the beginning of the program.[2]

Spiral development, the preferred process for implementing EA, suggests an even more radical departure from past approaches, because it envisions an ongoing process of evolutionary development of the system requirements, based on feedback loops from warfighters using field demonstrations, and from other stakeholders. As explained in the official DoD 5000 series guidance,

> In this process (Spiral Development), a desired capability is identified, *but the end-state requirements are not known at program initiation*. Those requirements are refined through demonstration and risk management; *there is continuous user feedback*; and each increment provides the user the best possible capability. *The requirements for future increments depend on feedback from users and technology maturation*.[3]

EA advocates claim many potential benefits from the adoption of the strategy, while skeptics raise numerous concerns about formidable barriers and challenges to implementing the policy effectively. Yet little documented objective experience and evidence exist to assess the policy and very little systematic analysis of what evidence does exist has yet been published. Nonetheless, almost all agreed at the time of its formal adoption that full implementation of EA using the

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[2] The authors are aware of no authoritative official DoD definition of "objective" and "threshold" capabilities. However, based on the implied meaning of the words in common DoD usage, the authors provide the following definitions. Objective capabilities are the full end-state capabilities envisioned for a new weapon system at the beginning of an acquisition program. Objective capabilities may be attained through a single-step-to-capability traditional program, or through an EA program that goes through the fielding of several interim systems that meet useful but lower threshold capabilities. Threshold capabilities are the minimum capabilities thought necessary to justify development of a new system or a new variant of the system.

[3] DoD (2003c). Emphasis added. The other process identified for implementing evolutionary acquisition is called incremental development. With incremental development, the end-state requirements *are* known. This is an important conceptual distinction that is discussed at length in the body of this monograph.

spiral development process by DoD would necessitate a major overhaul of DoD acquisition procedures, particularly in the areas of requirements management, budgeting, cost analysis, and elsewhere.

The overarching objective of this RAND research effort is to assist cost analysts and other elements of the Air Force acquisition management community in formulating cost analysis and program management policies and procedures that anticipate and respond to the prospect of more widespread use of EA strategies.[4]

This research effort adopted a three-pronged approach. First, the project team carried out a comprehensive review of published and unpublished reports and other studies on the theory and implementation of evolutionary acquisition. Second, it conducted a wide-ranging series of interviews with senior DoD and Air Force acquisition management officials regarding their understanding of the meaning and implications of DoD's mandated EA policies. Finally, it carefully reviewed five major space acquisition programs that have been recently restructured in accordance with EA concepts, in order to gain lessons learned to date on the implementation of EA, particularly in areas of relevance for cost analysts. The information on these case studies was derived from open sources and from interviews with senior program officials.[5] These are the five case studies reviewed:

- Space-Based Space Surveillance (SBSS) System
- Rapid Attack Identification, Detection, and Reporting System (RAIDRS)
- Global Positioning Satellite (GPS) III
- Space-Based Radar (SBR)
- Kinetic Energy Interceptor (KEI)[6]

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[4] This study, however, focuses largely on the implications of EA for the cost analysis community.

[5] The interviews were conducted by the authors and took place primarily during the first nine months of 2004.

[6] KEI is, of course, a Missile Defense Agency program. However, it was widely recommended to us by DoD officials as an instructive example of one innovative approach to implementing EA.

The authors chose to focus on major space programs for two reasons. First, space programs have recently grown significantly in relative importance for the future of the Air Force, and are central to DoD's plans for transformation of the U.S. armed forces. Second, the Air Force has recently completed a thoroughgoing review and complete overhaul of space acquisition policy. The new National Security Space Acquisition Policy (NSSAP) 03-01 guidance mandates evolutionary acquisition as the preferred acquisition approach for space programs. Most major new Air Force space programs have been structured, at least initially, as evolutionary acquisition programs based on spiral development.[7]

The programs examined as case studies are all in the very earliest stages of the acquisition process. Therefore, the lessons learned derived from them must be considered tentative and treated as provisional. In addition, it is important to note that the programs varied in size and complexity, as well as in the interpretation, definition, and application of the rather general guidance on the evolutionary acquisition strategies and processes provided by the DoD 5000 series and NSSAP 03-01. The authors provide a taxonomy of the different general types of programs in the list of case studies. (See pp. 39–40, 45–46.)

The next section summarizes the EA implementation lessons derived from these case studies, as well as overall findings for acquisition managers and for cost analysts.

EA Implementation Lessons Learned from Case Studies

Many of the issues, findings, and recommendations mentioned in this section are applicable to all major DoD defense acquisition programs, not only those conducted according to the EA process.

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[7] See Chapter One for organizations represented by interviewees. The applicability to nonspace programs of lessons learned derived from the use of EA on space programs is an area of some contention. The authors review the relevant evidence in the body of this study, and conclude that the EA lessons learned from space programs are largely applicable to other types of major DoD system acquisition programs.

However, there was a wide consensus among those interviewed that EA promotes certain program characteristics that make many of these issues and challenges more prominent.

EA programs require considerable additional up-front management planning and engineering workload and the budget sources to support them. (See below and Chapter Two, especially pp. 51, 88.) This situation arises from the necessity to map out the complex program structure implied by EA, which includes a series of separate, overlapping increments, each requiring the definition of operationally useful threshold and objective requirements, and each including formal milestone requirements mimicking a stand-alone program; and the additional system engineering and nonrecurring engineering to support the progression of upgrades and technology insertion that take place within and between increments. Also, additional up-front resources are required to support more extensive and continuously revised evolutionary costing efforts.

EA programs using the spiral development process should focus on capability mission objectives rather than traditional technical requirements. (See Chapter Two, especially pp. 46–48, 84–85.) With the spiral development process, the system requirements emerge and evolve over time. Therefore, the program focus, particularly at program inception, must be on capability objectives. This is a challenging approach, however, given the current acquisition regulatory and oversight environment; as a result, most programs examined while researching this monograph are tending to move away from spiral development and toward an incremental development process.[8]

After the initial formulation and stabilization of requirements at the beginning of a program or program increment (a process that does and should include significant feedback from the user communities), practical implementation of EA using the spiral development approach requires a more structured management of the user community feedback loop process. (See

[8] Unlike spiral development, the incremental development process assumes that the end-state requirements *are* known at the inception of the development process.

Chapter One, pp. 22–24, and Chapter Two, especially pp. 83–84.) Initial conceptual versions of EA strategies using spiral development envisioned constantly functioning feedback loops from the user community to fine-tune requirements and make sure that developers produce end products that meet real needs in the field. But actual experience in the early phases of the case study programs examined suggests that undisciplined feedback in the early concept development stages, particularly on programs with multiple user communities such as SBR, can lead to a counterproductive piling up of sometimes mutually inconsistent requirements, concepts, and technologies, and contributes to the challenge of controlling requirements creep.

Program managers believe that the use of EA on their programs will result in numerous different variants of the same system. This situation is expected to complicate logistics planning and implementation greatly. Plans will have to be made to update, retrofit, or dispose of earlier versions. (See Chapter Two, especially p. 84.) While none of the programs examined was nearly advanced enough to turn out operationally deployable hardware, it was the consensus view among program managers that the use of EA would produce multiple variants and greatly complicate support planning and implementation. Cost analysts also noted that this problem would make life-cycle cost (LCC) estimating more difficult.

The next section summarizes the broader overall findings from the review of the relevant published and unpublished literature, interviews with senior DoD acquisition managers, and case study analysis. The first subsection below summarizes general findings for acquisition management. The second subsection below summarizes the authors' overall findings for cost analysts.

Summary of Overarching Acquisition Management Findings

The new DoD guidance regarding EA (DoD 5000 series and NSSAP 03-01) permits great flexibility, but does not eliminate conceptual and definitional ambiguity. As a result, EA programs

vary considerably in their practical implementation approaches. (See Chapter Two, and Chapter Three, especially pp. 89–90.)[9] The persistence of definitional ambiguity and continuing lack of precise implementation guidelines have led to a range of differing interpretations of key terms and concepts in the structuring of EA programs. Such key EA concepts as feedback loops, and the difference between the spiral and incremental development processes, remain areas of debate and confusion in various sectors of the acquisition management community. Because of the serious implementation challenges posed by EA, especially using the preferred approach of spiral development, DoD should further clarify its guidance for implementing EA programs.

All of the case studies point to the conclusion that the capabilities and requirements definition and management processes are major challenges in all EA programs. Appropriate structuring of EA phases with operationally useful threshold requirements and mapping the path to overall objective capability are demanding tasks on most EA programs. (See Chapter Two, especially pp. 46–48, pp. 84–85.) This is particularly the case in large, complex hardware procurement programs using the spiral development process, where the objective end requirements are not known at the inception of the program. Areas of particular concern include the issues of structuring specific spirals or increments, defining operationally useful threshold requirements for specific spirals or increments, and mapping out the specific path to the objective end requirements. Preventing requirements creep is perceived as a significant challenge.

The use of the officially preferred spiral development process for implementing EA on major hardware acquisition programs greatly increases the level of program uncertainties, raising serious challenges for program managers in the current acquisition environment. (See Chapter Two, and Chapter Three, pp. 91–93.)

[9] Definitional ambiguity and lack of precise guidance have permitted not only significantly different approaches to be used on EA programs, but have also permitted certain policies that run counter to the original intent of EA advocates. Chapters Two and Three expound on this.

The very uncertainties that provide acquisition managers with valuable flexibility necessary to gain the expected benefits from EA through spiral development also raise considerable challenges for managers in the existing acquisition environment. Acquisition managers of large, complex hardware acquisition programs report that they are subjected to very strong pressures from political authorities, as well as from the requirements and cost analysis communities, to provide far more detail about the end stages of the program than they believe is feasible under the spiral development approach. As a result, many programs that started with the spiral development approach have been evolving toward an incremental acquisition approach, or something more akin to a traditional single-step-to-capability program with planned upgrades.

Therefore, the authors believe that evolutionary acquisition using the preferred approach of spiral development, as laid out in the most recent DoD 5000 and NSSAP 03-01 guidance, cannot likely be realistically implemented in the current political and acquisition environment on major DoD space programs, and even perhaps on other large-scale DoD hardware acquisition programs. At best, EA using spiral development may be one useful tool that can be used in some limited circumstances on software programs, on smaller-scale hardware programs, or perhaps on programs such as KEI that operate outside the traditional acquisition framework.

Summary of Cost Management Findings

EA programs require an evolutionary costing approach. By necessity, EA using the spiral development approach generally tends to lead to a heavy focus of the cost analysis effort on the initial spiral or increment, at the expense of other phases of the program. (See Chapter Two, especially pp. 49–50, 86–87.) Program managers and other acquisition managers interviewed noted that evolutionary costing is the only feasible and realistic approach to use on EA programs, especially those that employ the spiral development process. Evolutionary costing requires that the cost analysts work closely with gov-

ernment engineers for independent assessment of technological risk and schedule of the program. In addition, they need to work closely with the contractors to track the design and the technologies, and thus the costs, as they evolve. Cost models jointly developed by the Program Office and the prime contractor are often used. However, the inputs and the underlying assumptions to the cost model may be different. The authors found virtual unanimity among the cost analysts interviewed on all levels that evolutionary costing is feasible and that it works well, when government and contractor cost analysts work closely together in a nonpoliticized environment, and where general agreement has been reached among user communities on system requirements and the associated level of technological risk.

Overall, most cost analysts interviewed expressed generally positive views about EA. Nonetheless, lingering concerns did surface during the interviews regarding a variety of cost issues associated with EA. (See Chapter Two, especially pp. 48–51, 86–87.) Some of those concerns are listed below.

1. Committing the U.S. Air Force (USAF) to large, costly programs before the full cost implications of the program are well understood
2. Accurately assessing total program LCC, support costs, and retrofit costs based on sound and independent technical assessment of the program baseline
3. Adequately budgeting for the potentially high variability of cost outcomes arising from the high degree of uncertainty surrounding inputs to cost models
4. Accurately accounting for the potential cost implications of requirements creep arising from multiple users and planned insertion of technologies of uncertain future maturity.

A strong consensus emerged from the interviews with cost analysts that EA is an important and useful tool providing program managers with useful flexibility, and that the cost community can accommodate it adequately through the use of evolutionary costing. Nonetheless, there was recognition at least among some of those in-

terviewed that EA would increase the cost analyst's workload and require substantial interface with the engineers and the contractor.

EA as currently defined inherently results in increased uncertainties regarding technology development timelines and program schedule during the early phases of a program. If handled with care, these increased uncertainties can provide opportunities for greater program flexibility and program realism. At the same time, increased program uncertainties can pose difficult political and budgetary challenges for program managers within the current acquisition environment.

Abbreviations

AAC	Air Armament Center
ACAT	Acquisition Category
ACE	Acquisition Center of Excellence
ACTD	Advanced Concept Technology Demonstration
AFCAA	Air Force Cost Analysis Agency
AFCAA/TD	Technical Director, Air Force Cost Analysis Agency
AFSPC	Air Force Space Command
AoA	analysis of alternatives
AOC	Air Force Operations Center
ASC	Aeronautical Systems Center
ASP	Acquisition Strategy Panel
BMC3	Battlefield Management, Command, Control, and Communications
BMDO	Ballistic Missile Defense Organization
C2BMC	command, control, battle management, and communications
CAIG	Cost Analysis Improvement Group
CAIV	cost as an independent variable
CD	concept decision
CDD	capability development document
CDR	critical design review

COA	collaborative operations assessment
CONOPS	concept of operations
COTS	commercial off-the-shelf
CPD	capability production document
CR	concept refinement
CTF	combined task force
D/OT&E	developmental and operational test and evaluation
DAB	Defense Acquisition Board
DARPA	Defense Advanced Research Projects Agency
DAU	Defense Acquisition University
DCS	Defensive Counterspace
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DOTMLPF	doctrine, organization, training, materiel, leadership and education, personnel and facilities
DSCS	Defense Satellite Communications System
DSP	Defense Support Program (satellites)
DT&E	developmental test and evaluation
EA	evolutionary acquisition
ECP	engineering change proposal
ESA	electronically scanned array
ESC	Electronic Systems Center
FOC	full operational capability
FRP	full-rate production
FY	fiscal year
FYDP	Future Years Defense Plan
GAO	Government Accountability Office, formerly the General Accounting Office
GOTS	government off-the-shelf

GPS	Global Positioning Satellite
GRA	Government Reference Architecture
HALE	High Altitude Long Endurance
HRTI	high resolution terrain information
IC	integrated circuit
ICA	independent cost assessment
ICAT	independent cost analysis team
ICD	initial capabilities document
ICE	independent cost estimate
IDS	interference detection system
ILC	initial launch capability
IMPCS	interference monitoring power control subsystem
IOC	initial operational capability
IOT&E	initial operation test and evaluation
IPS	integrated program summary
JASSM	joint air-to-surface strike missile
JCS	Joint Chiefs of Staff
JDAM	joint direct attack munition
JPO	Joint Program Office
JROC	Joint Requirements Oversight Council
JSOW	Joint Stand-Off Weapon
JSTARS	Joint Surveillance Target Attack Radar System
KDP	key decision point
KEI	Kinetic Energy Interceptor
KPP	key performance parameter
LCC	life-cycle cost
LEO	low earth orbit
LRIP	low-rate initial production
MDA	Missile Defense Agency

MDAP	Major Defense Acquisition Program
MEO	medium earth orbit
MSX/SBV	Midcourse Space Experiment with Space-Based Visible Sensor
NAVWAR	navigational warfare
NGA	National Geospatial Intelligence Agency
NMS	National Military Strategy
NRO	National Reconnaissance Office
NSS	National Space Strategy
NSSAP	National Security Space Acquisition Policy
O&S	operations and support
ORD	operational requirements document
OSD	Office of the Secretary of Defense
OT&E	Operational Test and Evaluation
OTA	Other Transaction Authority
P3I	preplanned product improvement
PAF	Project AIR FORCE
PBA	price-based acquisition
PD	production and deployment
PDR	preliminary design review
PEO	program executive office
PRDA	program research and development document
R&D	research and development
RAIDRS	Rapid Attack Identification, Detection, and Reporting System
RDT&E	research, development, test, and evaluation
S&T	science and technology
SAF	Secretary of the Air Force
SAF/AQ	Secretary of the Air Force for Acquisition
SAIC	Science Applications International Corporation

SAIV	schedule as an independent variable
SAR	synthetic aperture radar
SBIRS	Space-Based Infrared System
SBR	Space-Based Radar
SBSS	Space-Based Space Surveillance
SBV	space-based visible sensor
S/C	spacecraft
SD	spiral development
SDD	system development and demonstration
SDIO	Strategic Defense Initiative Organization
SDR	system design review
SMC	Space and Missile Systems Center
SMTI	surface moving target indication
SPO	system program office
SR	Space Radar
SRR	system requirements review
SS	space sensor
SSA	Space Situational Awareness
SSAS	space system acquisition strategy
SV	space vehicle
T&E	test and evaluation
TDS	technology development strategy
TINA	Truth in Negotiations Act
TSAT	Transformational Satellite
UAV	unmanned aerial vehicle
UCAV	unmanned combat aerial vehicle
U.S.	United States
USAF	U.S. Air Force
USC	U.S. Code

USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics

CHAPTER ONE

Introduction: The Evolutionary Acquisition Concept

Overview

This monograph presents lessons learned on the implementation of evolutionary acquisition (EA) strategies for the procurement of major space defense systems. It focuses on issues of interest to the U.S. Air Force and other Department of Defense (DoD) cost analysis and acquisition management communities.

In May 2003, DoD promulgated its long-anticipated definitive revision of the 5000 series acquisition directives and instructions that govern the acquisition of major weapon systems.[1] These documents mandated EA strategies as the "preferred approach" to satisfying operational needs.[2] Formal adoption and full implementation of EA by DoD was widely viewed at the time as necessitating a major overhaul of DoD acquisition procedures, particularly in the areas of requirements management, budgeting, cost estimating, and elsewhere.[3]

The principal goal of EA strategies is to provide operationally useful capabilities to the warfighter much more quickly than traditional acquisition strategies. Instead of the old approach of "single

[1] The DoD 5000 acquisition policy guidance documents have been the key DoD publications establishing the basic process and structure for developing and procuring U.S. weapon systems since July 1971 (Ferrara, 1996).

[2] DoD first formally endorsed EA as the preferred acquisition approach in the DoD 5000 revised regulations issued in October 2000, but the definitive versions of the new regulations were not published until May 2003. See below for further discussion.

[3] For example, see Slate (2002) and Sylvester and Ferrara (2003).

step to full capability," evolutionary acquisition aims at achieving an overall objective end capability through the more rapid fielding of numerous operationally useful interim threshold capabilities[4] by pursuing less demanding intermediary increments or steps. Thus, DoD defines EA as an approach that

> delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept. (DoD, 2003c, Section 3.3.1)

Although reformers have advocated various types of incremental acquisition strategies for years, there had never been a DoD-wide implementation of such a strategy prior to the formal adoption of EA in October 2000 (with final revisions and clarifications in May 2003).[5] EA advocates claim many potential benefits from the adoption of the strategy, while skeptics raise numerous concerns about formidable barriers and challenges to effectively implementing the policy. Yet little objective experience and evidence exists to assess the policy, and very little systematic analysis of what evidence does exist has yet been undertaken.

The overarching objective of this RAND research effort is to assist cost analysts and other elements of the Air Force acquisition

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[4] The authors are aware of no definitive official DoD definition of "objective" and "threshold" capabilities. However, based on the implied meaning of the words in common DoD usage, this monograph provides the following definitions. The "objective" capability is the full end capability sought for the system following the completion of all development as laid out in the operational requirements document (ORD). Objective capability may be achieved either through a traditional single-step-to-capability program, or through a progression of interim programs, each of which meets a desired "threshold" capability. Threshold capability is the minimum system capability thought necessary to justify the development of a new system variant or system increment.

[5] See discussion below.

management community in formulating cost analysis and program management policies and procedures that anticipate and respond to the prospect of more widespread use of EA strategies. To meet this objective, this project aimed to answer these questions:

- What are the status, intent, and programmatic implications of evolutionary acquisition strategies as currently envisioned by senior DoD acquisition policymakers?
- What programmatic lessons learned are emerging from recent Air Force major space acquisition programs that incorporate key elements of evolutionary acquisition strategies as defined in the revised DoD 5000 series issued in May 2003 and incorporated into the National Security Space Acquisition Policy 03-01 (NSSAP 03-01)?
- What new policies and methods (if any) should the Air Force cost analysis and acquisition community adopt to assist most effectively in the implementation of evolutionary acquisition on space programs?

In order to provide some insight into possible answers to these questions, this research effort adopted a three-pronged approach. First, the researchers carried out a comprehensive review of published and unpublished reports and other studies on the theory and implementation of evolutionary acquisition. Second, the researchers conducted a wide-ranging series of interviews with senior DoD and Air Force acquisition management officials regarding their understanding of the meaning and implications of DoD's mandated EA policies. Finally, the researchers carefully reviewed five major space acquisition programs that have been recently restructured in accordance with EA concepts, in order to understand lessons learned to date on the implementation of EA. The information on these case studies was derived from open sources and from interviews with senior program officials.[6] The five case studies reviewed are as follows:

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[6] The interviews were conducted by the authors and took place primarily during the first nine months of 2004.

- Space-Based Space Surveillance (SBSS) System
- Rapid Attack Identification, Detection, and Reporting System (RAIDRS)
- Global Positioning Satellite (GPS) III
- Space-Based Radar (SBR)
- Kinetic Energy Interceptor (KEI)

Tables 1.1 and 1.2 list the organizations and the categories or positions of individuals interviewed for this research effort. In addition to the interviews identified in these two tables, the Air Force also invited the researchers to vet initial research findings from this research effort at a closed forum of senior government and industry officials organized by the Space and Missile Systems Center (SMC) Directorate of Contracting ("Teaming for Transformation," 2004). This forum included approximately 100 senior current and former DoD, Air Force, and industry leaders, many of whom provided important feedback for the project research approach and interim findings.

Later, this chapter discusses the rationale for focusing on space programs and for the selection of these specific acquisition efforts.

Table 1.1
Case Study Program Office Personnel Interviewed

Programs	Positions or Categories of Individuals Interviewed
SBSS	Chief, Acquisition Management
RAIDRS	Program Manager (SMC/Space Superiority Program Office); Deputy Program Manager (SMC/Space Superiority Program, Contracting); Acquisition Developments, Acquisition Center of Excellence (SMC)
GPS III	Deputy Program Manager (SMC/GPS III Program Office); Space Segment Branch Chief; Contractor Acquisition Support staff (Science Applications International Corporation [SAIC])
SBR	Program Manager (SMC/SBR Program Office); Chief, SBR Business Operations; Deputy Chief, SBR Business Operations; Contractor Acquisition Support staff (Tecolate Research, SAIC, Aerospace Corp); Acquisition Developments, Acquisition Center of Excellence (SMC)
KEI	Program Manager; KEI contracting and cost analysis personnel

Table 1.2
Other Organizations and Individuals Interviewed

Organization	Position of Categories of Individuals Interviewed
SMC Directorate of Contracting	Deputy Director, Contracting Chief, Pricing (Resource Mgmt, Pricing); Chair, Contracting Committee
SMC Comptroller	Staff personnel
SMC Development and Transformation Directorate	Chief, Integration Division
SMC Acquisition Center of Excellence	Staff personnel
SMC Directorate of Systems Acquisition	Staff personnel
SMC Industry Day	Industry and government acquisition personnel

Why This Project?

Drawing from the brief preceding discussion, the basic rationale justifying the research reported in this monograph can be summarized as follows:[7]

- Despite numerous attempts at clarification by the Office of the Secretary of Defense (OSD), the definitions of critical terms related to EA and the key practical elements of specific strategies for implementing EA remain ambiguous and lack clarity, in the view of many cost analysts and acquisition managers.
- Advocates and opponents of EA present numerous claimed theoretical benefits or likely challenges that will arise from the widespread implementation of EA. Yet little systematic evidence has been collected from actual programs to support the claims of either advocates or opponents of EA.

[7] This subsection is based largely on the authors' distillation of key points derived from numerous interviews with senior DoD and Air Force cost analysts and acquisition managers, as well as a wide survey of the relevant published literature.

The remainder of this subsection reviews these points in more detail. It begins, however, with a brief historical examination of the motivations and objectives behind the formulation of EA, and how its advocates originally perceived it.

Dissatisfaction with the Traditional Acquisition Process and the Promise of Evolutionary Acquisition

For decades, observers have criticized the growing length of time required to design and develop major DoD weapon systems, particularly when contrasted with the typical development times for complex commercial products. This criticism became particularly strident in the 1990s, as the cycle times for the development of new generation commercial electronics continued to shrink, leading to situations where electronic components and subsystems designated for use in such complex weapon systems as the F-22 fighter actually became obsolete and disappeared from the marketplace prior to the completion of system development.[8]

The traditional DoD acquisition process, as laid out in the DoD 5000 acquisition policy guidance series, was essentially a rather inflexible, serial, linear, step-by-step approach determined in great detail by an extensive accumulation of DoD bureaucratic tradition, formal policy guidance, regulations, and public law. In addition to the widely recognized problem of inordinately long development cycles that commonly spanned ten to fifteen years, two other key problems particularly caught the attention of senior DoD officials in the late 1990s:[9]

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[8] Studies conducted by the Semiconductor Industry Association and others in the 1990s indicated that the average life cycle of commercial-grade integrated circuits (ICs) had declined to two to five years, down from five to twelve years in the 1980s. A large weapon system at this time typically took around ten years to develop and was expected to remain in the inventory for at least 30 years. Thus several generations of ICs might emerge and disappear during the system design and development phases alone. Prior to the first flight of the F-22 fighter in September 1997, an Air Force study concluded that hundreds of electronic parts planned for use in the fighter had already or would soon become obsolete, and would no longer be available (Lorell et al., 2000).

[9] For a good discussion of the perceived problems with the traditional acquisition process and how they encouraged the formulation of EA, see Wellman (2003).

1. The traditional acquisition process often necessitated the identification and detailed formulation of all the program system performance requirements at the very earliest stage of the program, often before a full understanding of the ultimate system performance requirements could be attained, and when the technologies to achieve the necessary capabilities were either immature or unknown. Nonetheless, these requirements, once formally approved, would often become cast in stone as an unchangeable template against which all aspects of the program were judged, regardless of changing or newly emerging operational needs. This could lead to bitter mutual recriminations between the acquisition and the operational user communities, as well as criticism from Congress, on who was responsible for fielding a system of less than optimal capability. The Operational Test and Evaluation (OT&E) community would then dutifully and rigorously test each system to ensure it precisely met the original formal written requirements, even though those requirements might no longer reflect current operational needs because they were formulated so early in the program.
2. The traditional system, following the dictates of public law, required the formal development of a detailed life-cycle cost (LCC) estimate during the early developmental stages of the program. These point estimates might be required to cover many years of technology and system development, as well as procurement, and operations and support periods of 40 years or more. Not surprisingly, these estimates often proved to be unrealistic, because so many uncertainties and technology risks exist early in the developmental cycle. The result was often major cost overruns, schedule slippage, criticism from Congress, and mutual recriminations over who was at fault among the acquisition, user, and contractor communities.[10]

[10] The authors are grateful to RAND colleague and former Air Force acquisition official John C. Graser for his succinct formulation of these problems on which they draw heavily.

By the mid-1990s, the senior DoD leadership was seriously considering a major overhaul of the entire DoD acquisition process, including a major revision of the DoD 5000 policy documents, to fix these and other perceived procurement process problems. EA rapidly became a central component in this acquisition reform effort. Reformers were inspired by a variety of innovative acquisition approaches being tried outside the mainstream acquisition process at this time. Many of the most important concepts that lay behind the EA concept emerged from early acquisition reform legislation developed in conjunction with Congress and the Defense Advanced Research Projects Agency (DARPA) in the early 1990s to facilitate operational and hardware development of innovative new platforms and technologies, among the most prominent of which were large surveillance unmanned aerial vehicles (UAVs) (Leonard and Drezner, 2002).

The most important acquisition reform tools developed at this time included the Advanced Concept Technology Demonstration (ACTD) designation, and the use of Section 845/804 Other Transaction Authority (OTA). These and other reform measures permitted DARPA to experiment simultaneously with hardware and operational concepts for development of surveillance UAVs without being burdened by the vast regulatory and statutory requirements of the standard DoD acquisition process. Most importantly for the future emergence of the EA concept, the ACTD approach did not necessitate a complete and precise understanding of the eventual operational performance requirements for the system at program inception, or the determination of detailed technical system requirements for the hardware. Rather, the ACTD concept envisioned a highly flexible exploratory technology demonstration process, which would lead to the unfolding of the precise operational utility and technological requirements for a system through feedback from field testing and experimentation with demonstrator prototypes.

With the apparent early success of DARPA ACTD programs such as the Global Hawk and DarkStar UAVs,[11] DoD began searching for ways to transfer some of the key aspects of the more flexible approach of ACTDs to the mainstream world of traditional acquisition programs. Since DoD officials realized that the whole traditional acquisition process could not, and probably should not, be jettisoned in its entirety, the focus shifted to several key elements of ACTDs and other experimental approaches that were thought to be most likely to bring about beneficial results.

On a broad conceptual level, two key principles that were eventually folded into the emerging EA concept could be summarized as follows:

1. The breaking down of large, long, inflexible traditional acquisition programs into several, much shorter, lower risk, more manageable phased increments or spirals
2. The transformation of the early phases of the research and development (R&D) segment of acquisition programs into more flexible technology demonstration programs that would permit greater experimentation with requirements, operational concepts, and technology applications.

Ambiguity and Lack of Clarity in Definitions and Implementation Strategies

By the beginning of the new century, these basic concepts underlying EA had gelled in the minds of senior DoD acquisition managers and reformers, eventually leading to the major revision of the DoD 5000 series promulgated in October 2000 and clarified in May 2003. As noted previously, the revised 5000 series placed a central emphasis on EA as the preferred acquisition approach. The initial promulgation of EA, however, led to considerable confusion and uncertainty within

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[11] Despite its promising beginning, the DarkStar UAV was cancelled in February 1999 due to design shortcomings. While the Global Hawk is widely considered to be an operational success, the program experienced significant cost growth, particularly in 2004–2005 during development of a heavily modified new version of the UAV.

the traditional acquisition community. This was partly because many of the fundamental concepts underpinning DoD's EA strategies were not new, and appeared to some observers to be similar to related concepts tried in the past. Confusion arose in some quarters regarding how EA differed from the earlier concepts. In addition, the original official formulations of EA were less than perfectly clear regarding the definition of many concepts, and the precise means of implementing the policy. Finally, many if not most of the old regulatory requirements, which were usually waived in ACTD programs and other innovative approaches, appeared to some observers to have remained embedded in the new revised 5000 series regulations, which seemed to conflict with the basic goals of acquisition reform.

As ably documented by Richard Sylvester and Joseph Ferrara among others (Sylvester and Ferrara, 2003), the adoption of strategies related to EA has been advocated by various DoD and other studies for at least twenty years. Indeed, as far back as the late 1960s, some DoD officials began urging adoption of a related acquisition strategy called preplanned product improvement (P3I), in which systems would be designed from their inception to incorporate later upgrades and newer technologies as they matured.[12] Phased acquisition was another acquisition reform measure with some characteristics similar to EA that was often advocated in the 1970s and 1980s.[13] Another related concept, spiral development, gained widespread support in the computer software industry during the 1980s.[14] Indeed, according to Sylvester and Ferrara, as early as 1984, the logistics commanders of all three services endorsed evolutionary acquisition as a legitimate strategy and advocated development of a formal policy guide.

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[12] This includes unpublished 1981 RAND research on product improvement strategies.

[13] For example, from 1976 through 1978, RAND examined the phased acquisition strategy through case study analysis of the C-5A military transport, the TF-41 jet engine, and the F-111 fighter bomber. These case studies resulted in unpublished internal reports. Some of the results of this work were published in Lee (1983).

[14] A very influential article advocating an evolutionary approach to software development was published by Barry Boehm (1988). See also Boehm and Hansen (2001).

Yet while forms of evolutionary acquisition and related concepts had been discussed and advocated for years, prior to 2000 none of them were ever codified in the 5000 series as the preferred DoD approach to acquisition. In 1998, Jack Gansler, then Under Secretary of Defense for Acquisition & Technology, launched a series of reviews, called the Section 912 studies, aimed at reforming the overall DoD acquisition process. The following year, the Section 912 study team as well as the Chairman of the Joint Chiefs of Staff (JCS) formally endorsed EA. Soon afterward, Gansler, who enthusiastically supported EA, established a dedicated team to revise the DoD 5000 acquisition policy guidance series to reflect the findings of the Section 912 study. In October 2000, DoD published a major revision of the 5000 series Acquisition System guidance regulations that mandated evolutionary acquisition strategies relying on a spiral development process as the preferred DoD acquisition approach (DoD, 2000b).

The publication of the new 5000 series regulations led to widespread uncertainty and confusion among DoD acquisition managers regarding the terminologies associated with evolutionary acquisition and the appropriate means for implementing the policy (Sylvester and Ferrara, 2003; Slate, 2002; "Evolutionary Acquisition and Spiral Development," 2002). Differing interpretations of new strategies and various terminologies soon proliferated. The differences and policy distinctions, if any, among concepts such as evolutionary acquisition, phased acquisition, incremental development, spiral development, and preplanned product improvement, as well as more traditional concepts such as block upgrades, planned modifications, and engineering change proposals (ECPs), remained unclear and ambiguous to many DoD acquisition managers.[15]

This confusing situation led to a lengthy and sometimes difficult process of attempting to clarify the meaning and practical implications of the new policy and how it might be implemented, as documented in part by Sylvester and Ferrara (2003). This process began in earnest with a memorandum issued on April 12, 2002, by E. C.

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[15] For example, see Burke (2002).

“Pete” Aldridge, then Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]) (Aldridge, 2002a; also see “Evolutionary Acquisition and Spiral Development,” 2002). This memorandum openly recognized that “some confusion” persisted regarding the definition of key EA terms, their relationship to other terms, and the implications of EA for various aspects of the acquisition process such as “contracting and requirements generation.” In an attempt to reduce confusion and ambiguity, an attachment to the memorandum included detailed approved definitions of evolutionary acquisition, spiral development, preplanned product improvement, and other concepts.

The Aldridge memorandum helped refine the EA concept further, but did not end the confusion and uncertainty surrounding implementation of EA. A year and a half later, as part of a wider effort to overhaul and streamline the entire acquisition system, Deputy Secretary of Defense Paul Wolfowitz issued two new and important memoranda. The first cancelled the revised Department of Defense Directive (DoDD) 5000.1 from October 2000 and other 5000 series regulations, and the second provided interim guidance and directed preparation of revised regulations within four months (Wolfowitz, 2002). These memoranda were followed by extensive discussion and debate among all the major stakeholders involved in defense acquisition. The intensity of that debate and the number of process issues that needed to be addressed delayed approval of the revised acquisition regulations for many months. Much of the discussion revolved around issues related to EA. Finally, in May 2003, Deputy Secretary Wolfowitz signed the new DoDD 5000.1 and Department of Defense Instruction (DoDI) 5000.2 regulations (DoD, 2003a, 2003c).

The new 5000 series documents contain much more explicit policy guidance and definitions of EA terminology than earlier documents. DoDD 5000.1 and DoDI 5000.2 make three fundamental points regarding EA. First, “evolutionary acquisition strategies are the preferred approach to satisfying operational needs” (DoD, 2003a, p. 3). Second, there are two different developmental processes to implement EA strategies: incremental development and spiral develop-

ment. And, finally, of the two, "spiral development is the preferred process for executing such strategies" (DoD, 2003a, p. 3).

Of critical importance of course were the definitions finally adopted in these documents for EA terminology, and particularly how spiral development and incremental development relate to EA. DoDI 5000.2 provides the definition of EA quoted at greater length at the beginning of this chapter, the key phrase of which notes that EA is "an evolutionary approach" that "delivers capability in increments, recognizing, up front, the need for future capability improvements" (DoD, 2003c, p. 4).

The incremental development process for implementing EA is defined as a process where "a desired capability is identified, an end-state requirement is known, and that requirement is met over time by developing several increments, each dependent on available mature technology" (DoD, 2003c, p. 5). However, the *preferred* process of spiral development, as defined in DoDI 5000.2, suggests a much more radical departure from traditional practice:

> In this process [spiral development], a desired capability is identified, *but the end-state requirements are not known at program initiation*. Those requirements are refined through demonstration and risk management; *there is continuous user feedback*; and each increment provides the user the best possible capability. *The requirements for future increments depend on feedback from users and technology maturation.* (DoD, 2003c, p. 5. Emphasis added.)

Of the two processes for implementing EA, the preferred approach—spiral development—is the most challenging. The precise nature of the spiral development process as applied to the development of weapon system hardware was not spelled out in detail in the DoD guidance documents, and remained an area of some contention and debate. As touched on above, the spiral development concept originated some years earlier from the commercial and academic software development worlds, but was not originally thought of as being applicable to hardware development. Dr. Barry Boehm is widely credited with developing and popularizing the spiral develop-

ment process while Chief Scientist at TRW, Inc., in the mid-1980s as a means of reducing risk and increasing responsiveness to customer needs in large commercial software development projects ("What Is Spiral Development?" 2003; see also Boehm, 2000). A key element of the original spiral concept was the progressive serial development of numerous software prototypes during each developmental spiral or increment; these prototypes would be tested by users, and the operational insights gained would then be funneled back through a formal feedback loop into the requirements and development processes for the next spiral.

Most early advocates of spiral development in the weapon system acquisition arena emphasized a similar concept of spiral prototype development with feedback loops (Little, 2002). The precise nature and extent of the feedback loop process in large defense equipment programs eventually became an area of contention. Most observers came to view the feedback loop process for hardware (as opposed to software) as only taking place as a *subprocess to help refine requirements within* each increment, each of which would be already fairly well defined at the beginning of the increment (see, for example, McNutt, 2000; and Brown, 2003). The precise meaning and extent of the feedback loop process remains vague and ill defined in the most recent DoD 5000 series guidance. As quoted above, DoDI 5000.2 clearly states that in spiral development "(t)he requirements for future increments depend on feedback from users and technology maturation" (DoD, 2003c, p. 5) But it also states that "*there is continuous user feedback*" (DoD, 2003c, p. 5) during spiral development, implying that it takes place both within spirals and between spirals. The questions of field testing of progressive prototypes and implementing feedback loops from users into the R&D process during specific spirals or increments later raised many perceived challenges for program managers, particularly regarding the issue of requirements creep, as touched on further in Chapter Two.

Thus, EA implemented through spiral development, as defined in the May 2003 revision of the 5000 series documents, could be and was interpreted as representing a potentially radical departure from traditional DoD acquisition policy. While EA entails a phased, in-

cremental approach to achieving a capability, the mandated preference for the use of the spiral development process to implement this strategy indicates that the end-state system requirements are not known at program inception, but rather evolve throughout development through an iterative process. Older, related concepts, such as P3I, differ significantly from EA using spiral development in that with P3I both the end-state capabilities *and* system requirements are known at program inception. This distinction later proved to be of crucial importance for cost analysts and for budgeters, as discussed further in Chapter Two.

Another critical distinction between EA—using either the spiral development or incremental development process—and older, related concepts, such as P3I, is that with EA the specific number, makeup, content, and objectives of the various upgrade increments throughout the program life cycle are largely unknown at program inception. In the case of P3I, the specific upgrades and their timing and phasing are well known in advance.[16]

Thus, in spite of the clarifications provided by the revised DoD 5000 series in May 2003, the formal adoption of EA using the preferred approach of spiral development or incremental development raised many major questions for acquisition program managers regarding the implementation of life-cycle cost estimating, budgeting, system requirements formulation, and other key program processes, some of which are discussed in greater detail below. As Sylvester and Ferrara so rightly noted in 2003,

> Because EA has never been implemented in a wholesale fashion within the DoD, no one is exactly sure of how its implementation will play out, but everyone is pretty sure that *full implementation of EA, as called for in the 5000 series, will probably mean*

[16] The authors are unaware of any definitive, official DoD documents that clearly and consistently distinguish between EA, P3I, block upgrades, and other historical concepts with similarities to EA. One quasiofficial source makes the following distinction regarding EA and P3I, which is slightly different from what is shown above: Unlike EA, this source claims that "pre-planned product improvement (P3I) is a traditional acquisition strategy that provides for adding improved capability to a mature system" ("Evolutionary Acquisition and Spiral Development," 2002).

> *major changes in the way DoD has traditionally done business.* (Sylvester and Ferrara, 2003, p. 10. Emphasis added)

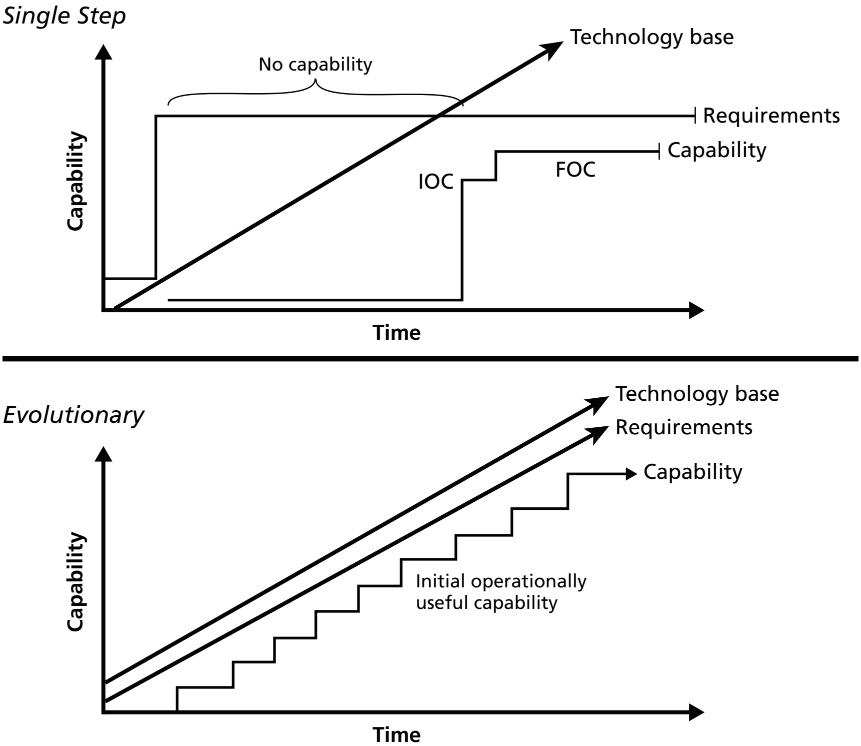
Theoretical Benefits and Challenges: What Did the Reformers Intend EA to Be, and What Process Did the New 5000 Series Documents Establish?

Claimed Benefits. The advocates of EA using spiral development argue that the benefits that are likely to accrue justify accepting the difficult challenges that may be required to implement the policy. As already noted, the most important benefit claimed for EA was more rapid fielding of operationally useful capability than the old single-step to-full-capability approach. Other claimed benefits include the following:

- Reduced likelihood of major R&D schedule delays and cost overruns due to the focus on the use of mature technologies and the promotion of more realistic system performance expectations
- Enhanced requirements formulation process, which is much more responsive to the warfighter's real operational needs due to constant feedback from the user communities
- Rapid insertion of the latest technologies into the system, thus avoiding the problem of obsolete parts and subsystems.

As noted earlier, the key to achieving these benefits through EA is the separation of large, complex programs that envision a "single step to capability" into many smaller, more manageable phased steps or increments. Figure 1.1 contrasts a highly simplified theoretical graphic comparison of the traditional approach to the EA approach. As shown in the top part of the figure, the traditional process is a single-step-to-capability approach, wherein a single, very long, high-risk R&D and procurement effort is undertaken aimed at achieving a rigid set of very demanding capabilities based on technologies which may be uncertain or immature at the beginning of the program. In

Figure 1.1
Single Step Versus Evolutionary Acquisition Approach



SOURCE: Lumb (2004, p. 12).
NOTES: IOC = initial operational capability; FOC = full operational capability.
RAND *MG431-1.1*

the EA approach, shown on the bottom of Figure 1.1, such a program is broken up into many smaller, shorter, more manageable increments or spirals.

Each EA program increment is treated in theory as if it is a separate program with its own unique developmental and procurement phases.

A series of less demanding, phased capability steps are identified that more closely match the likely maturity of the component technologies at any given time. Thus the available technologies are matched with more realistic requirements and capability expectations

over time, resulting in multiple steps of increasing capability made available much sooner to the warfighter. In principle, each step, while not resulting in the ultimate objective capability, provides the warfighter with an improved capability that is superior to the existing capability in the field and that is operationally useful. Ultimately, the same high objective capability is attained, but not before the warfighter has received many earlier variants with an interim capability that exceeds existing fielded equipment.

The building blocks or steps that make up an EA program are actually viewed as a series of multiple, staggered, simultaneous development iterations, increments, or spirals. Each of these iterations is, for all practical purposes, a minisystem development program, which includes most of the standard phases and regulatory and oversight requirements laid out by DoDI 5000.2 for overall system acquisition programs. These iterations build on the core increment to produce improved variants or upgrades of the system that emerge from the core increment. This concept is graphically illustrated in Figure 1.2.[17]

The second key aspect of EA is made up of three elements. The original advocates of EA insisted that no system variant being developed in a given increment should be permitted to enter into full-scale development (that is, formal acquisition program initiation) unless it is determined that (1) the technologies are mature, (2) the requirements are well-defined, and (3) the funding has been programmed.

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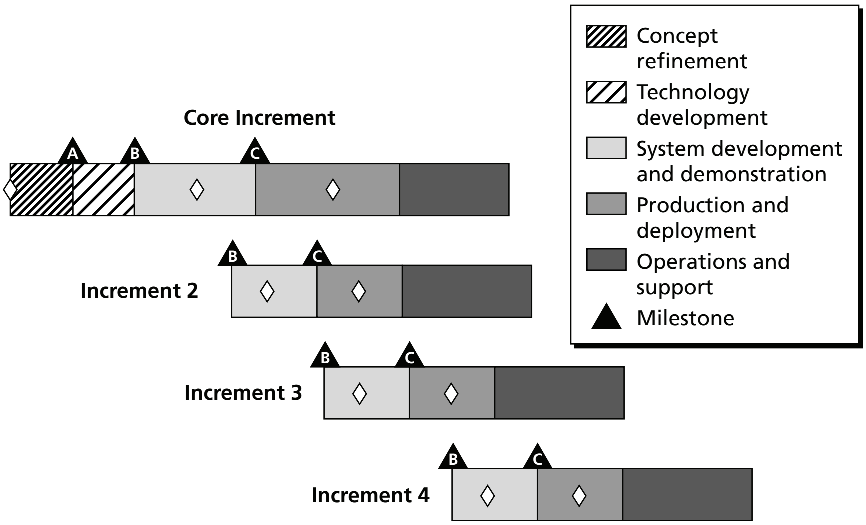
[17] As is discussed in greater detail later in this monograph, the new revised EA process actually leads to a substantial increase in the process complexity of programs. For example, *each increment* is required to have all the supporting documentation for the following categories of factors: (1) approved operational requirements; (2) performance, cost, and schedule goals; (3) operational and live fire testing (if required); (4) compliance with all acquisition oversight requirements; (5) a formal acquisition strategy plan that includes logistics planning, manpower, personnel and training, environmental and security factors, protection of critical program information, and spectrum management; and (6) other information tailored to the unique circumstances of the program. For details, see DoD (2002). Also see Defense Acquisition University (2003).

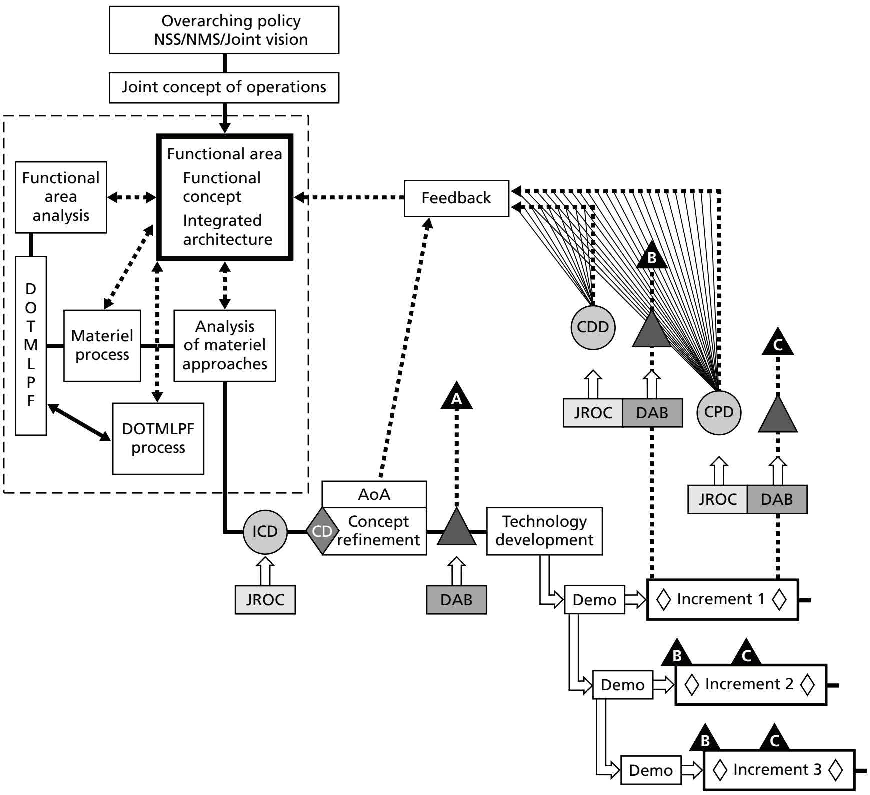
Figure 1.2
EA Implies Multiple, Staggered, Simultaneous Iterations



SOURCE: Lumb (2004, p. 13).
RAND *MG431-1.2*

To achieve this objective, EA advocates sought to transform the earliest phases of each EA program increment or spiral into a much more flexible technology and concept demonstration phase. The main purposes were to ensure that available technologies had reached adequate levels of maturity, and that the system requirements and cost estimates had been sufficiently refined. Strict entrance criteria for moving into the next phase—now called system development and demonstration (SDD)—would be required, since this phase would constitute acquisition program initiation. The goal was to promote the exclusive use of sufficiently mature technologies to avoid high developmental risk, the achievement of stable system requirements, and the provision of full funding for the entire increment or spiral. Program initiation (Milestone B) would not be approved until these criteria were met. These key aspects of the EA process are illustrated in Figure 1.3, which shows the overall technology development phase after Milestone A, and discrete technology demonstration phases preceding each Milestone B decision for each separate increment.

Figure 1.3
Overall EA Requirements and Acquisition Process Depiction



SOURCE: U.S. Department of Defense (2003c, Figure 2). Also see Defense Acquisition University (2003).

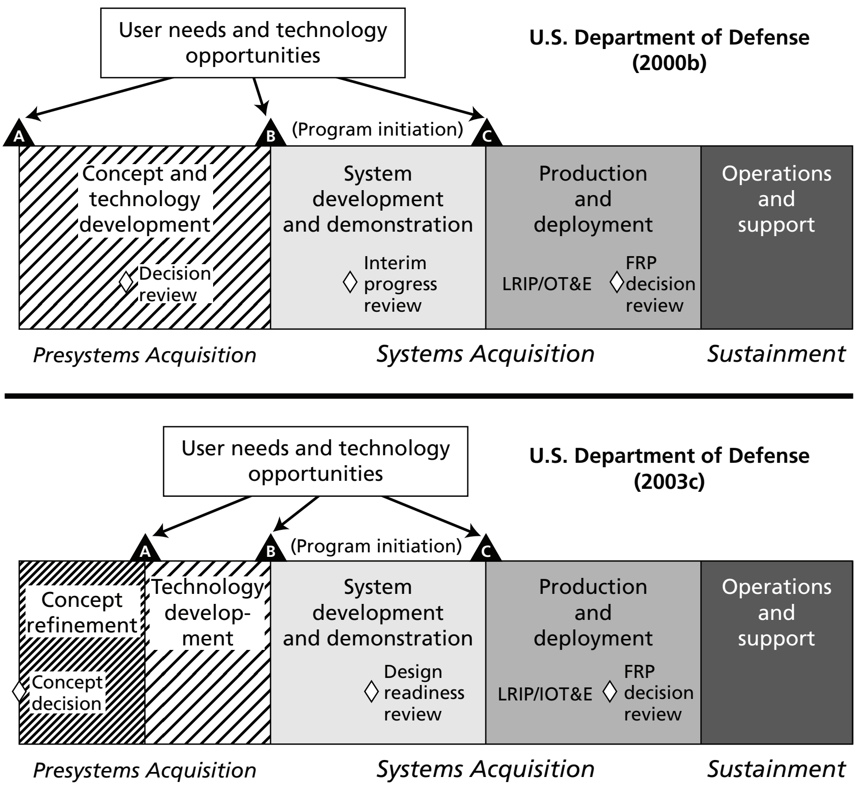
NOTES: NSS = National Space Strategy; NMS = National Military Strategy; DOTMLPF = doctrine, organization, training, materiel, leadership and education, personnel and facilities; ICD = initial capabilities document; CD = concept decision; AoA = analysis of alternatives; CDD = capability development document; CPD = capability production document; DAB = Defense Acquisition Board; JROC = Joint Requirements Oversight Council.

RAND *MG431-1.3*

Figure 1.4 shows how the structuring of the overall acquisition program, as well as each discrete EA increment, were changed by the revised 5000 series in order to further implement these policies. The major changes were the old concept and technology development

phase was divided into two separate phases (concept refinement and technology development); Milestone A was moved back to the end of the concept refinement phase and before entrance into the technology development phase; the old decision review assessment activity was moved forward to the beginning of the new concept refinement phase and renamed the concept decision assessment activity; and the

Figure 1.4
Main Differences Between the Old and New DoDI 5000.2 Acquisition Management Frameworks



SOURCE: Derived from Defense Acquisition University (2003).
NOTES: LRIP = low-rate initial production; OT&E = operational test and evaluation; FRP = full-rate production; IOT&E = initial operational test and evaluation.
RAND *MG431-1.4*

old interim progress review assessment activity became the design readiness review. The intent was in essence to add an additional formal milestone (the concept decision point was similar to the old Milestone 0), and focus the Milestone A decision on planning for the technology development phase. The purpose was to promote greater emphasis on requirements definition and technology maturation efforts prior to program initiation, both for the overall program and for each individual EA increment.

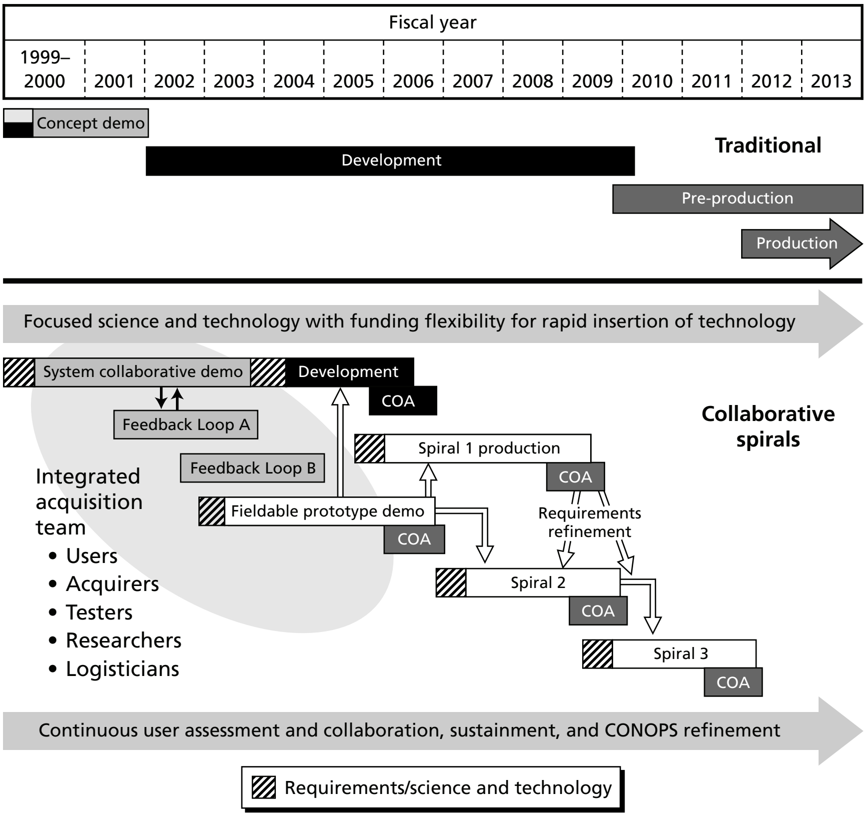
The exit criteria from the technology development phase are characterized as the successful identification of an "[a]ffordable increment of militarily-useful capability with technology demonstrated in a relevant environment, and a system that can be developed for production within a short timeframe" (Lumb, 2004, p. 19). Thus, the intent was to not pass through Milestone B (formal program initiation) nor enter into full-scale development (system development and demonstration, or SDD) until a clearly understood military capability goal had been identified and a relatively low-risk technological solution to provide the capability was available. As the authors' space case studies show, these objectives proved difficult to satisfy on many EA programs, however.

Thus EA aims at harmonizing and synchronizing the evolution of military requirements and capability objectives with the evolution and maturation of technology. This leads, according to EA advocates, to the much more rapid fielding of operationally useful systems through developmental programs that are much less prone to cost growth and schedule slippage because they depend on mature technologies and more realistic capability objectives.

EA supporters claim that implementing EA through the spiral development process has the added advantage of producing systems that are much more responsive to the warfighters' and logisticians' needs. This is because spiral development, as noted above, envisions multiple feedback loops during every development increment wherein warfighters, logisticians, and testers can constantly provide inputs and corrections into the development process based on field experience, using prototypes or technology demonstrators. Thus the requirements and even the capabilities of the system constantly evolve

in response to real world experience. One typical Air Force stylized graphical representation of this collaborative approach is shown in Figure 1.5.[18]

Figure 1.5
Feedback Loops Refine Requirements in Spirals: Notional Unmanned Combat Aerial Vehicles (UCAVs) as USAF Spiral System R&D Illustration



SOURCE: Based on chart presented in Little (2002).
NOTES: COA = collaborative operations assessment; CONOPS = concept of operations.
RAND *MG431-1.5*

[18] On EA's enhanced responsiveness to users, see Brown (2002).

In a traditional program, the major generic program phases (concept development, development, preproduction, and production) are separate and distinct, with little cross interaction, as shown in the top half of Figure 1.5. This contrasts with a spiral approach, where an integrated acquisition team made up of users, acquirers, testers, researchers, and logisticians work together on numerous phased but overlapping development cycles that are linked by information feedback loops. Thus the overall system requirements evolve over time based on user and logistician experience, the progress of technology development, and so forth. As one senior Air Force official put it, in spiral development "the requirements evolve from user learning" (Little, 2002, p. 8).

The graphic overall portrayal of the constant requirements feedback loop from the initial requirements generation through each milestone review of each increment is also portrayed in DoDI 5000.2, as shown in Figure 1.3.

Thus, the DoD 5000 regulations as revised in May 2003 contained significant process and structural changes to the overall theoretical acquisition process. To summarize, these were expected to be the key benefits of EA that would flow from these changes:

- Much faster fielding of operationally useful capability to the warfighter
- Lower risk of program cost growth or schedule slip due to phased insertion of more mature technology
- More responsive requirements process that leads to more combat-effective and -supportable systems
- More rapid insertion of new technologies.

Potential Challenges for the Cost Analysis Community. Despite the attractive benefits claimed for EA, even its most fervent supporters recognize that it poses several potential implementation challenges for the cost estimating and acquisition management community. For example, a typical recent DoD briefing advocating EA made the key point that "[w]hile EA should get systems to the field faster, there are

some complex areas that need attention" (Defense Acquisition University, undated, p. 25).

Probably the most commonly mentioned challenges facing the cost analysis community are as follows:

- Costing spiral acquisition programs (or increments) where the end-state requirement is not known at program inception (by definition), and which continuously evolves throughout program life
- Access to independently assessed technical and programmatic information for each of the spirals.

Since the initial adoption of EA in the revised DoD 5000 regulations issued in October 2000, numerous acquisition experts have raised concerns regarding the challenges posed by spiral development to DoD Comptroller functions such as those related to budgeting, financing, contracting, and cost estimating (see Sylvester and Ferrara, 2003). Theoretically and by definition, neither the acquisition managers nor the ultimate users know what the final or objective system requirement is at the beginning of a spiral development program. Yet most of the traditional statutory and regulatory imperatives dictating cost estimating and budgeting requirements are still applicable. At the beginning of a program, how can the cost of a system and its overall development program be estimated, much less its total expected life-cycle costs (LCC), when no one knows what the objective requirement for that system will end up being, or what that system will look like? In the minds of many observers, this remains the central challenge posed by EA for cost analysts, and may point to the need for EA programs to maintain larger cost reserves in their budgets to address the "known unknowns" (for example, see Brown, 2003).

Expert observers also identified a variety of other challenges for cost analysts posed by EA, which are related to the overlapping phased increments that characterize EA, early on. These challenges involved the complexities of costing, contracting, and managing EA programs made up of multiple, simultaneous, staggered increments or

subprograms for different variants in different stages of R&D, production, operation, and support.

As illustrated in Figures 1.2, 1.3, and 1.5, evolutionary acquisition—whether using the spiral development or incremental development process—resembles a collection of parallel overlapping but closely interconnected subprograms, each in a different phase of the formal acquisition process. Such a program structure obviously entails additional management complexities compared to a traditional single increment program. Each increment or subprogram of an EA program has its own formal milestone and other program reviews, requiring the generation of all the usual formal documentation including that for costs. Thus, some observers believed that an EA program would greatly increase overall management and oversight workload for program offices. Instead of managing one large program, under the traditional approach, a program office might face the prospect of managing numerous complex subprograms all in different phases of the acquisition process, and going through different milestones requiring different types of oversight and reporting.

Some of the hypothetical challenges potentially raised by the unique structuring of EA programs with numerous overlapping increments are summarized as follows:

- Anticipating and costing future retrofit programs that may be deemed necessary to upgrade earlier variants with technology developed in later increments, spirals, or iterations
- Estimating increased indirect costs from the need for greater process and up-front management investments in the early stages of the program
- Costing increased workload required to prepare for the larger number of milestone and submilestone reviews necessary for multiple simultaneous iterations
- Determining the effects on cost improvement curves of multiple simultaneous configurations in different stages of R&D and production, plus possible simultaneous retrofit upgrade programs

- Estimating operations and support (O&S) costs for a force made up of numerous different configurations in different stages of the acquisition process.

Potential Challenges for the Acquisition Management Community. In addition to these more tactical concerns relevant to cost analysts, there are numerous other concerns identified by various observers and critics related to broader strategic challenges posed by EA related to the effective management of large weapon system acquisition programs. Some of the most common concerns of this type mentioned by critics include the following:[19]

- With the ultimate requirements unknown at program inception, EA may encourage DoD to commit to early iterations of a program with little insight into the ultimate cost and technical risk entailed in reaching the full system capabilities.[20]
- Contractors may allocate the relatively easy developmental tasks to early iterations of the program, slipping the more difficult tasks to later iterations, in the hopes that DoD will become irrevocably committed to the program.
- Program offices and contractors may be tempted to mask troubled programs that are failing to meet requirements by relabeling them as EA programs.
- The existing temptation to rob funding intended for later iterations to pay for funding shortfalls or cost overruns in current iterations will be increased.

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[19] Many of these as well as other theoretical concerns regarding the implementation of EA are identified in Sylvester and Ferrara (2003), as well as elsewhere.

[20] According to the revised 5000 series documents, in a spiral development program, the end capabilities are known, but the requirement is not. What this apparently means is that the desired end capabilities are known (for example, such as tracking tactical moving targets from space over an entire theater of operations), but the precise technologies and technical means of achieving those capabilities are not known (for example, the precise numbers of space vehicles in the constellation, type of radar technology and antenna array to be used on the space vehicles, or the architecture of the communication links).

- The user community as well as the developmental and operational test and evaluation (D/OT&E) communities may have difficulty formally determining when the end requirement has been achieved in a spiral development program.[21]
- The lack of clearly defined end requirements at program inception may contribute to frequent changes in requirements as well as requirements creep throughout development, factors that historically have been identified as contributing to cost growth and schedule slippage.

There is little doubt that the full adoption of EA poses many potential implementation challenges for cost analysts and acquisition managers. Yet practical experience with implementing EA remains sparse, so that the various views on the severity of the challenges posed by EA implementation versus the value of the potential benefits to be derived from EA are often still a matter of speculation or theory. Little analysis to date has been conducted on what little practical experience has been accumulated.

In short, no one presently knows with any certainty what the impact of full EA implementation will be over the long term on the acquisition process and acquisition program outcomes. No detailed DoD guidance of which the authors are aware exists to assist the cost analysis and acquisition management community in implementing the details of programs structured in accordance with the precepts of EA. This report attempts to review systematically the practical experience with EA that does exist in a small group of specific programs to help shed greater light on these issues and move toward a better understanding of how acquisition management and cost analysts are contributing to the implementation of EA in the real world.

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[21] According to the revised DoD 5000 documents, each increment must pass through a formal test and evaluation phase just like a traditional system. However, in some nonspace EA programs such as the Global Hawk and Predator unmanned aerial vehicles (UAVs), prototypes have been shipped to active operational theaters for combat testing and use prior to formal operational testing.

Research Approach and Organization of This Monograph

As noted in the introduction to this monograph previously, this research effort adopted a three-pronged approach. First, the authors conducted a comprehensive review of published and unpublished reports and other studies on the theory and implementation of evolutionary acquisition. Second, the authors systematically interviewed a variety of senior DoD and Air Force officials from the cost analysis and acquisition management community regarding their understanding of the meaning and implications EA policies as spelled out in 5000 series regulations promulgated in May 2003. Finally, the authors carefully reviewed five major space acquisition programs that have been recently restructured in accordance with the new space system acquisition guidance (see below for specific cases), in order to understand lessons learned to date on the implementation of EA on military space programs.

Why Space Programs?

Early on, the authors decided to select all the major case studies from a specific, focused area: military space programs. There are two basic reasons for this decision: the growing importance of space for DoD and the Air Force and the recent extensive and very detailed overhaul of DoD space acquisition policy that designated EA as the preferred acquisition approach. The rationale for selecting space programs as case studies is discussed in more detail below.

As mentioned previously, the first reason for focusing on space acquisition is that the relative importance of space programs for OSD and the Air Force as key transformational systems has recently and rapidly grown. Over the last several years, the U.S. Air Force has invested on the order of $6 billion a year in unclassified space programs. In January 2001, a special high-profile space commission mandated by Congress and chaired by Donald Rumsfeld stressed the growing importance of space to U.S. national security. The space commission formally recommended that the President review and revise U.S. national space policy to better promote the employment of space assets "to help speed the transformation of the

U.S. military" (Commission to Assess United States National Security Space Management and Organization, 2001, p. 7). Two years later, a key follow-on study, the so-called Young Panel Report, concluded that "U.S. national security is critically dependent upon space capabilities and that dependence will continue to grow" (DoD, 2003b, p. 1). This increasing emphasis on space continues to be reflected in DoD's fiscal year (FY) 2006 budget request to Congress. As one observer noted, reductions in traditional Air Force and Navy programs "are at the core of Defense Secretary Donald Rumsfeld's drive to transform the military into a more flexible and integrated force, with space initiatives slated to receive a steadily growing slice of the defense pie" (Pasztor and Karp, 2005). While the Air Force may gradually phase out up to 25 percent of its existing fighter aircraft force structure, spending on Air Force space programs since 2002 has risen by nearly $2 billion, or about 20 percent.

As a reflection of the growing importance of space, and in response to the recommendations of the Space Commission, Secretary Rumsfeld directed OSD and the Air Force to consolidate authorities across the national security space community. As a result, in 2002, the planning, programming, and acquisition of all national security space programs were concentrated into the hands of the Under Secretary of the Air Force, thus greatly increasing the importance of the role played by the Air Force in major space acquisition programs.[22]

The second rationale for focusing on space in this study is the extensive and detailed effort recently undertaken by the Air Force to restructure space acquisition policy guidance, with an emphasis on EA. In 2003, the Air Force launched an ambitious and detailed effort to overhaul the entire national space acquisition system, which was now concentrated for the first time under its direct

[22] In early 2002, the Under Secretary of the Air Force, Peter B. Teets, was delegated authority as the Air Force Acquisition Executive for Space for Air Force space programs and DoD Milestone Decision Authority for all DoD space Major Defense Acquisition Programs (MDAPs). In July of that year, Teets became the DoD Executive Agent for Space. In addition, Teets is dual-hatted as the Director of the National Reconnaissance Office (NRO).

supervision. This overhaul included the formal incorporation of evolutionary acquisition as the preferred acquisition approach.

The main objective of the Young Panel, as mentioned previously, was to develop a strategy for overhauling and reforming the national space acquisition system, in response to the space commission findings and the concentration of space acquisition authority in the hands of the Air Force. The Young Panel concluded that the space acquisition system had become profoundly dysfunctional and was in dire need of reform: "The Government capabilities to lead and manage the [space] acquisition process have seriously eroded" (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2003, p. 3). Furthermore, the Young Panel concluded that the space acquisition process was characterized by "excessive technical and schedule risk," as well as "unrealistic budgets and unexecutable programs" (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, 2003, p. 2). Space acquisition reform was seen by many as crucial to gain congressional support for increased spending on space programs. As one observer noted, "[y]ears of chronic cost overruns, delays and technical problems have made lawmakers leery of moving too fast on ambitious Air Force space concepts" (Pasztor and Karp, 2005).

A unique set of formal acquisition regulations, guidance, and instructions, separate from the standard DoD 5000 series, governs the acquisition of military space systems. The Young Panel findings led to a thorough revision of these policies under direct Air Force supervision. In October 2003, less than six months after the publication of the Young Panel findings, DoD issued its revamped National Security Space Acquisition Policy Document Number 03-01 (NSSAP 03-01) through the Office of the Under Secretary of the Air Force for Space Acquisition.[23] Because of the unique nature of space systems, NSSAP 03-01 differs in many significant respects from the acquisi-

[23] U.S. Department of Defense (2003b). A revised and updated version was issued about a year later, which changed acquisition Phase C (build, test, and launch) to a design completion phase, and added a new build and operations Phase D. However, the sections directly relevant to EA were not altered (U.S. Department of Defense, 2004).

tion guidance laid out in the new DoD 5000 series issued in May. However, in one key respect of special interest here, both sets of guidance documents are identical: They both emphasize that evolutionary acquisition is the preferred strategy for DoD acquisition. NSSAP 03-01 includes the same definitions with the same distinctions for spiral development and incremental development as DoDI 5000.2.

NSSAP 03-01 explicitly requires a considerable amount of specific documentation on each program's use of EA. It mandates that each program manager describe the EA strategy that will be used in the space system acquisition strategy (SSAS), a crucial document that must be updated for each major phase of the program. For major DoD space systems, the reasons that an EA strategy is adopted or not adopted must also be carefully justified and documented.[24] The required program cost estimates must include "all blocks that will make up an evolutionary acquisition to the extent that subsequent blocks can be defined" (DoD, 2004, p. 2).[25] In addition, the rationale for dividing the program into specific spirals or increments must be explained. At each key decision point (KDP) in a program, the program office is required to prepare an integrated program summary (IPS), which constitutes the spiral development plan for programs using the spiral development process.[26]

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[24] According to NSSAP 03-01, a major space defense acquisition program is defined as one in which the eventual expenditure on research, development, test, and evaluation (RDT&E) is expected to exceed $356 million in fiscal year (FY) 2000 constant dollars, or $2.190 billion in FY 2000 constant dollars on procurement, or that is designated as "major" by the designated DoD authority. The dollar requirements were established by statute in FY 1990 dollars. The definition is established by 10 USC 2430 and is the same as the DoD definition for an Acquisition Category I (ACAT I) program. The dollar amounts have been updated in accordance with procedures outlined by the law (DoD, 2004, Section 3.1.1).

[25] While this provision appears to provide flexibility for the need to cost spirals precisely far in the future, expensive high-profile space programs such as SBR tend to be held to a much higher and stricter standard by Congress. See Chapter Two.

[26] KDPs are the most important program review milestones for DoD acquisition programs. They usually take place between major phases of the program (such as between the study phase [Phase A] and the design phase [Phase B]). At KDPs, overall program progress is evaluated by the designated senior DoD officials, who make a decision regarding the readiness of the program to proceed to the next acquisition phase.

Some of the potential tensions and challenges posed by EA for cost analysts and acquisition managers are evident in the detailed documentation requirements mandated by NSSAP 03-01. Most importantly, the new space acquisition policy guidance requires as much detailed information as possible regarding objectives, content, and estimated costs of specific increments or spirals. Yet, in theory, the use of EA makes it difficult to project the future content and makeup of specific spirals or increments beyond the earliest phases of the program. This is particularly true of a program that adopts the spiral development process, in which by definition the end-state requirements are not known at program inception. The authors therefore flagged this issue to investigate in more detail through this examination of case studies.

Do EA Findings Based on Space Program Case Studies Apply to Other Types of Programs?

As noted previously, military space programs differ in several important respects from other types of DoD defense acquisition programs. The differences are large enough to justify the existence of the separate set of acquisition regulations referred to previously, the NSSAP 03-01. To what extent do the differences between space programs and other types of DoD acquisition programs reduce the applicability of the findings of this study to other types of weapon system acquisition programs?

This is a perfectly legitimate and reasonable question, which cannot be answered with 100 percent certainty. The authors adopted four approaches to dealing with this question. The first involved a wide ranging series of interviews with senior DoD and Air Force acquisition officials knowledgeable in EA, in order to gain their insights into issues and challenges related to implementing EA on all types of DoD programs across the entire spectrum of program and system types. The second involved the careful delineation of those aspects of space programs and space acquisition policy which differ from other types of DoD acquisition programs, and then offer some informed DoD observations on how these might affect the generalizability of EA findings based on space programs, if at all. The third entailed a

comprehensive survey of other studies and the open literature regarding the application of EA to nonspace programs, and a comparison of the findings of these studies to this project's findings.

The fourth and perhaps most persuasive approach involved reviewing extensive past published and current RAND field research on unmanned aerial vehicles (UAVs), in particular the General Atomics Predator tactical UAV and the Northrop Grumman Global Hawk High Altitude Long Endurance (HALE) UAV, to see if the experience with EA on these programs is consistent with what is found on space programs. The reason these UAV cases are so useful for comparison is that they are widely considered by many DoD officials and other observers as key test cases for EA. Fortunately, RAND has conducted extensive acquisition policy research in the past, and is continuing such research in the present on these programs.[27] According to an earlier RAND study, the Predator program became the de facto prototype of the ACTD process (Thirtle, Johnson, and Birkler, 1997) which, as noted previously, directly led to the formulation of the initial DoD EA strategies. A separate study, conducted by a senior acquisition manager who has worked on the Global Hawk program virtually since its inception, recently observed that "it is probably not too presumptuous to state that Global Hawk is viewed today by DoD leadership as the test case for the determination of the efficacy of Evolutionary Acquisition as it relates to Spiral Development" (Pingel, 2003, p. 8).

The concluding chapter of this monograph presents the authors' findings on EA derived from the space program case studies and the more general interviews with senior DoD experts on EA, and assesses their applicability to other types of programs by reviewing and comparing the findings of other studies and RAND studies on Global Hawk, Predator, and other UAV programs. This chapter is limited to

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[27] The lead author of this monograph is a coproject leader of an ongoing RAND study sponsored by the Assistant Secretary of the Air Force for Acquisition on UAVs, with a special focus on Global Hawk and Predator, and is responsible for assessing the effects of EA on these programs for acquisition managers and cost analysts. Past major published RAND assessments of these and other UAV programs include Drezner and Leonard (2002) and Thirtle, Johnson, and Birkler (1997).

a quick review of how space programs differ from other types of DoD acquisition programs and how NSSAP 03-01 differs from the DoD 5000 regulations with respect to EA, and offers a few observations on the relevance of these differences.

Based on this case study research, interviews with senior DoD officials, and review of the open literature, the authors conclude that space programs differ from other acquisition programs in at least four important respects:

1. Space programs are characterized by very small procurement numbers of space vehicles (SVs). According to DoD, "[s]atellite programs produce from 1–25 satellites—6 being average," compared to procurement numbers in the hundreds or even thousands for such items as tactical fighter aircraft or smart munitions (U.S. General Accounting Office, 2003, Appendix III).
2. All SV component testing cannot be done in an operational environment (space), because of the high cost of space launches and the limited number of operational SVs in any system.
3. A larger percentage of total program expenditures take place in the early phases of a space acquisition program compared to other acquisition programs (Adams, 2004).
4. Space program technology development continues on longer in the procurement process than is typical (or desirable) in other types of procurement programs, according to the U.S. Government Accountability Office (GAO), formerly the General Accounting Office. This situation, according to GAO, appears to have been formalized in the NSSAP 03-01 regulations. However, DoD strongly disputes GAO's interpretation of NSSAP 03-01 (U.S. General Accounting Office, 2003).

While these differences appear to be real (at least the first three), it is unclear what impact, if any, they have on the applicability of EA lessons derived from space program case studies to other types of DoD programs. While the 2003 GAO report strongly criticizes NSSAP 03-01 for promoting a high-risk approach to acquisition by allowing the beginning of the production stage to overlap with on-

going technology development, DoD vigorously disputes GAO's findings and insists that NSSAP 03-01 enshrines and promotes the same basic EA principles that underpin DoD 5000.2.

While DoD's response to the 2003 GAO report recognizes differences between space and other programs, it stresses that "NSS Acquisition Policy 03-01 and DoDI 5000.2 are consistent in their intent," particularly in the area of evolutionary acquisition and the importance of proof testing technologies, reducing technological risk, incorporating feedback from the user, and implementing regular program and cost reviews, all key components of an EA approach as laid out in DoDI 5000.2.

It can be argued that the only significant difference between the structuring of space programs based on NSSAP 03-01 and other programs based on DoDI 5000.2 is that two key decision points (Milestones B and C) come earlier for space programs, as shown in Figure 1.6. Furthermore, there are more major program reviews in the early phases of a space program, ensuring user feedback and technology maturity.[28]

NSSAP 03-01 emphasizes that space programs by their very nature must be conducted with an EA approach, and have for some time been carried out that way. The document includes the same wording as DoDI 5000.2 on EA, and adds that "[e]volutionary acquisition has been a cornerstone for space system development since the early 1960's" (DoD, 2004, p. 9). All space programs using EA are required to include a formal description of their EA strategy in their Acquisition Strategy documentation and a spiral development plan in their integrated program summary (IPS).

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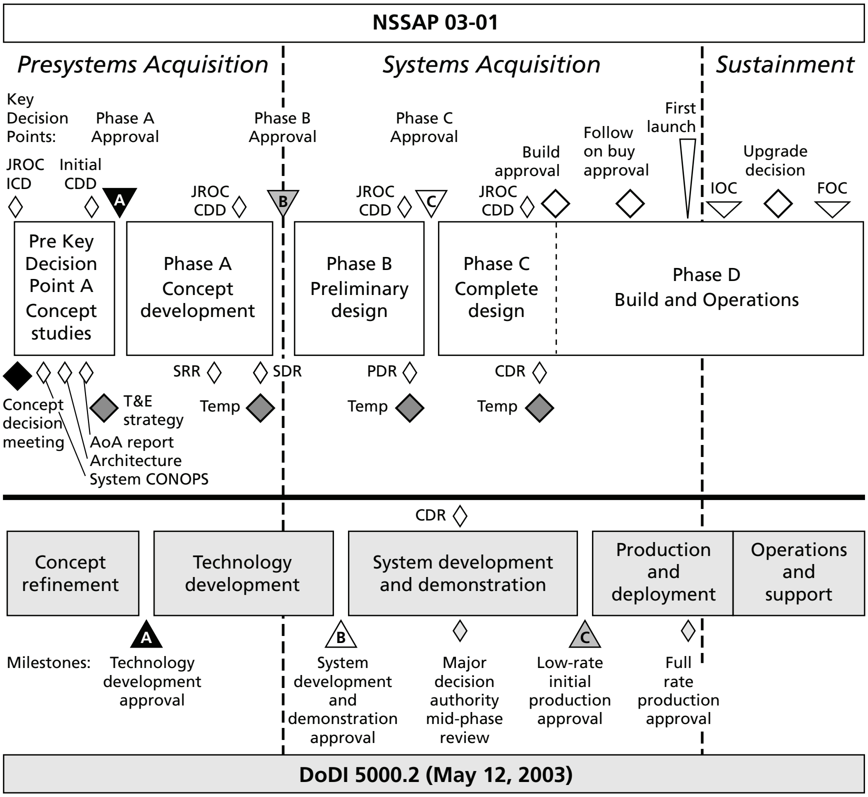
[28] These include the system requirement review (SRR) in the later part of Phase A, the system design review (SDR) at the beginning of Phase B, the preliminary design review (PDR) in the middle of Phase B, and the critical design review (CDR) at the transition from Phase B to Phase C.

Figure 1.6
DoDI 5000.2 Versus NSSAP 03-01: Acquisition Phase Comparison



SOURCE: U.S. Department of Defense (2004, Figure 1, p. 5).

NOTES: SRR = system requirements review; SDR = system design review; PDR = preliminary design review; CDR = critical design review. The December 2004 revision of NSSAP 03-01 significantly changed the space acquisition phasing laid out in the earlier document, apparently in an effort to reduce space program risk. In the updated NSSAP 03-01, Phase C was split into two separate new phases. Phase C became the complete design phase and a new phase was added that was designated Phase D and called build and operations. Several key design review events are moved in the new phasing, apparently in response to criticism that the October 2003 version permitted programs to enter into the acquisition phase too early in the development process, thus raising program risk. In the new version, the SDR is moved back to the end of Phase A, and thus becomes part of the entry requirements for Milestone B. The PDR is moved to the end of Phase B and becomes, in effect, part of the entry requirements for Milestone C. The CDR is moved far to the right and immediately precedes the new build approval milestone and entry into the new Phase D. This, in effect, provides more time to mature the design and technologies before committing to a final design.

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At the end of the day, however, the authors are inclined to agree with the DoD observation included in its response to GAO that "it is difficult to accurately compare NSS Acquisition Policy 03-01 to the new DoDI 5000.2, since it is too early to judge what effect the new 5000 series will have on traditional acquisition challenges" (DoD, 2003b, p. 23).

Based on the quick review here of how space programs differ from other types of DoD acquisition programs, and how the formal NSSAP 03-01 policy differs from the DoD 5000 regulations with respect to EA, the authors conclude that based on these factors there is no consensus and little hard evidence either way regarding the applicability of space program lessons learned on EA to other types of DoD defense acquisition programs.

It is for this reason that the authors rely heavily in the last chapter of this monograph on a comparison of these findings from space programs to past and ongoing acquisition research on EA as applied to Global Hawk and Predator as well as other UAVs, and to other available research that has assessed real-world experience with EA on nonspace programs. It is from this evidence that the authors conclude that the findings from space programs are reasonably robust and largely applicable to a much broader spectrum of DoD programs. The underpinnings for this conclusion are discussed in detail in Chapter Three, especially in "Applicability of EA Findings from Space Programs to Other DoD Defense Acquisition Programs."

Case Study Selection and Methodology

As noted previously, the authors selected the following five space programs as case studies for this research effort.

- Space-Based Space Surveillance (SBSS) System
- Rapid Attack Identification, Detection, and Reporting System (RAIDRS)
- Global Positioning Satellite (GPS) III
- Space-Based Radar (SBR)
- Kinetic Energy Interceptor (KEI)

The goal was to review systematically the five selected programs to gain insights and lessons learned into how cost analysts and acquisition managers are actually implementing EA in the real world. The authors selected these programs based on the recommendations of cost analysts and acquisition managers at the Air Force Space and Missile Systems Center (SMC) and elsewhere, whom the authors informally surveyed.[29] A consensus of officials consulted agreed that this collection of cases was a good representative sample of a variety of different types of space programs attempting to implement EA as mandated in the new DoD space acquisition policy guidance. These cases are representative of a wide spectrum of Air Force space programs in terms of scale of effort (from relatively modest programs such as RAIDRS to potentially large programs such as SBR), and in specific details of EA implementation strategies, as well as other factors. In addition, these cases were among those whose program offices agreed to participate in the case study effort.

The U.S. Air Force, through its Space and Missile Systems Center (SMC), is the lead acquisition management authority for the first four programs. The KEI program, however, is in many respects a special case. It is managed by DoD's Missile Defense Agency (MDA), not the U.S. Air Force. MDA acquisition programs are integrated into a unique, overall, integrated missile defense acquisition strategy, but are implemented under the guidance of the standard DoD 5000 series of acquisition guidance documents. The authors selected the KEI program because it is a space weapon system program that is being implemented in part through the rigorous application of DoD-mandated EA concepts. The program is also of special interest because the Program Manager, Terry Little, is a well-known pioneering acquisition reformer who has led some of the most innovative recent

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[29] Based on expert recommendations, the authors had originally also intended to include a sixth program, the transformational satellite (TSAT), which is part of the transformational communication program. Limitations in the research schedule and resources, however, prevented us from including TSAT as a full case study. Therefore, it is not discussed in this monograph, although it has also adopted an EA approach.

acquisition programs in the U.S. Air Force, and has been directly involved in the development of the Air Force approach to EA.[30]

Organization of This Monograph and Important Qualifications

Chapter Two of this monograph begins with a discussion of overarching issues raised by all the case studies, then proceeds to a brief description of the specific case studies' program structures and acquisition approaches, and ends with a presentation of the findings from the case studies of relevance to cost analysts and acquisition managers.

Chapter Three presents a summary overview of the authors' findings and some concluding observations.

As discussed briefly, it is legitimate to question whether findings regarding EA based on space program case studies are fully relevant to other types of major DoD acquisition programs. The authors believe these findings are reasonably robust across the whole spectrum of major DoD programs. The reasoning behind this conclusion is discussed in detail in Chapter Three.

It is also important to note here, however, that the space programs examined as case studies are all in the very earliest stages of the acquisition process. Therefore, the lessons learned that the authors derived from them must be considered tentative and treated as provisional. In addition, it is important to note that the programs varied in size and complexity, as well as in the interpretation, definition, and application of the rather general guidance on the evolutionary acquisition strategies and processes provided by the DoD 5000 series and NSSAP 03-01. The authors provide a taxonomy of the different general types of programs in the list of case studies (see Chapter Two, pp. 45–46).

Another significant qualification the reader should keep in mind is that this study focuses almost exclusively on the acquisition man-

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[30] Terry Little was the influential program manager in the 1990s of two key Air Force acquisition reform pilot programs, the joint direct attack munition (JDAM) and the joint air-to-surface strike missile (JASSM). Later, he became director of the Acquisition Center of Excellence (ACE) under the Assistant Secretary of the Air Force for Acquisition. For accounts of these and other Air Force acquisition reform programs and their implications for cost analysts, see Lorell et al. (2000) and Lorell and Graser (2001).

agement and cost analysis community. The authors did not consult with or interview representatives of the user communities. Therefore, the findings are heavily slanted toward the perspective and problems of the acquisition community. The user communities may have a completely different take on these programs. Understanding their perspective is of course crucial to an overall high-level assessment of the efficacy of EA to the Air Force as a fighting organization. Since the charter for this study directed the authors to assess the implications of EA for the acquisition and cost community, the authors leave such an overall higher-level assessment of EA to other analysts in the future. Hopefully this study provides at least some useful input for such a future study.

CHAPTER TWO

Evolutionary Acquisition in Practice: Five Case Studies

Introduction

This chapter presents brief summaries of the case studies of the five space system acquisition programs selected as examples of the new approach to evolutionary acquisition. As noted in Chapter One, these programs are as follows:

- SBSS system
- RAIDRS
- GPS III
- SBR
- KEI.[1]

Before reviewing the individual case studies, the monograph briefly discusses various general characteristics of all the programs, as well as some crosscutting issues particularly relevant to acquisition management and cost analysis. First, the monograph looks at crosscutting acquisition management issues. Then it examines crosscutting cost analysis issues. The five principal case studies are then summarized and briefly reviewed. The chapter ends with some additional observations and findings drawn from the specific case studies.

[1] As mentioned previously, the authors initially planned to include a sixth program, the transformational satellite (TSAT) within the transformational communication program. Because of resource and schedule constraints, the authors removed this program from the list of case studies.

Crosscutting Acquisition Management Issues

Program Maturity

It is important to note that all five of the case study programs studied in detail were in very early program stages at the time the authors interviewed program officials and collected information.[2] This was unavoidable given that the authors wanted to examine programs that were implementing the new DoD EA guidelines from scratch, since those guidelines were not issued in final form until well into 2003 (and then revised at the end of 2004). All five programs were thus in the presystems acquisition phase, focused primarily on pre-Key Decision Point A (KDP-A) or study Phase A activities. Thus all the programs were involved in basic concept refinement issues and in architecture development and technology refinement. Given the very early phase of most of these programs, it is not surprising that many basic uncertainties remain regarding program structure, requirements, acquisition approach, and other fundamental issues. Therefore, the broad applicability of the lessons learned and challenges encountered to date on these programs for acquisition managers must be viewed with extreme caution. Nonetheless, the authors believe that enough experience had been gained on these programs dealing with many of the basic challenges posed by EA to provide useful insights and lessons for future programs.

Variations in Evolutionary Acquisition Program Approach

The authors found that the case studies varied widely in terms of the aspects of EA that they emphasize, and their application of EA terminology and principles. Sometimes variations existed even within programs. For example, at least one program originally labeled each of its EA developmental phases as "spirals," presumably reflecting the DoD-preferred EA process of spiral development. Later, these phases were called "increments" rather than "spirals."

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[2] Almost all interviews and information collection on case studies took place during the first nine months of 2004.

This research indicates that variations in the use of terminology have essentially two causes. The first is the continuing ambiguity and confusion over the basic terminologies used in EA, even following the attempted clarifications promulgated in the new DoD 5000 guidance issued in 2003. Perhaps more significant, this research suggests that all the programs have over time begun to move away from the preferred "spiral" approach toward an "incremental" approach, as defined in the 5000 guidance documents. This appears to be a response to a variety of pressures emanating from the existing political, statutory, and regulatory acquisition environments. Most important, issues soon emerged on most of these programs regarding the definition of requirements and cost estimating approaches for specific EA development phases, which tended to encourage movement away from a spiral development approach and toward an incremental development approach. More on these issues is said below and elsewhere.

Program Scale, Complexity, and Other Factors: A Taxonomy

The authors also noted that such basic program characteristics as program size (in terms of budget and cost), technological and programmatic complexity, nature of the user communities, and other program characteristics, varied considerably among case studies. Perhaps the only feature common to all of them is that none has yet moved past the concept development phase, as mentioned previously. The authors developed a taxonomy that divides the case study into three categories for analytical purposes. The three categories are loosely based on relative program cost, complexity, and acquisition style.

The first two programs considered, SBSS and RAIDRS, are relatively modest, low-cost, low-complexity acquisition programs that so far have been conceptually structured into only two basic increments. At this stage, the first increment is by far the most important. For the *initial* increment for each program, the end requirements are relatively well defined, allowing them to be treated effectively as standalone programs. Concepts for the final end system after a second increment are both more ambitious and much less well defined because objective end requirements are still quite uncertain. In each case, it is possible that the initial system from the first planned increment will

evolve in a direction not now anticipated, leading to the possible launch at some time in the future of an entirely new program to meet the objective requirements now envisioned for the second increment (once those requirements are clearly defined).

The next two case study programs, GPS III and SBR, are more complex and potentially much higher cost than SBSS and RAIDRS. Notionally they are structured into multiple increments.[3] Just how many increments remained uncertain in mid-2004, because the threshold and objective requirements, as well as the specific content and structuring of many of the increments, was still in the process of being determined. Desired objective capabilities for the two end systems, however, have largely been determined by their many potential user groups.

The final case study program, KEI, is in many respects a unique case because of the multitude of innovative acquisition measures being applied to the program and the nonstandard aspects of all MDA major acquisition programs. Not only does the KEI program apply EA, but it employs numerous other acquisition reform strategies such as price-based and capabilities-based acquisition.[4]

The authors found some subtle differences in the findings and lessons learned based on the category of program as outlined in the taxonomy discussed here. These differences, however, are minor, and will be noted later when relevant.

Managing the Capabilities and Requirements Processes

All of these case studies point to the conclusion that the capabilities and requirements definition and management processes are major challenges in all EA programs. All major acquisition programs must confront uncertainties and disagreement about necessary capabilities and system requirements to provide the capabilities. This situation is made much more challenging and complex by EA. This is because

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[3] In 2005, SBR was restructured essentially as a technology demonstration program. See specific case study below.

[4] For an assessment of price-based acquisition (PBA), see Lorell, Graser, and Cook (2005).

EA programs tend to treat each separate increment or spiral much like a separate program, which requires its own separate definition of capabilities and requirements. This tendency is reinforced by the new DoD 5000 document guidance and congressional guidance that require each increment to pass through most of the same formal milestones, program reviews, and documentation as the overall program. At the same time, each increment is not truly a stand-alone program, but rather a part of a much larger single effort. As a result, acquisition managers have to justify the operational usefulness of the end product of each increment as part of an operationally useful threshold capability, while at the same time justify the need to continue with follow-on increments in order to meet a needed objective capability further down the road. Such an approach also requires the development of a carefully laid out plan that maps the specific path through several increments that achieve first the threshold capability and end up with the desired objective capability.

Thus the application of EA in the current regulatory environment requires program managers early in a program to define the specific content and structure of each increment or spiral, the content and timing of the threshold and objective capabilities, and the precise path to the end goal. In the cases examined, the authors found that system program offices (SPOs) tended to rely heavily on competitive contractor studies to assist them in these tasks. Credible assessment and future projection of the relative maturity of key enabling technologies are among the most demanding and difficult aspects of these studies. As many program officials interviewed confirmed, DoD's transition from requirements-based to capabilities-based acquisition approaches is greatly increasing technical and management flexibility, but it is also increasing program complexity and expanding the upfront work load on the SPO and contractors.

Another related area of concern encountered from program officials during the interviews regarded the challenge of controlling requirements and capabilities creep in EA programs. The 2003 Young Panel Report identified "undisciplined definition and uncontrolled growth in system requirements" as one of the "basic reasons for the significant cost growth and schedule delays in national security space

programs" (DoD, 2003b, p. 2). While all major defense acquisition programs must cope with this issue, space programs confront a particularly challenging environment because of the multiple and continuously proliferating number of user communities. It is not surprising, then, that many program officials interviewed expressed concerns about the open-ended and more flexible nature of the requirements process, which is a key attribute of the spiral development process, with constant feedback loops from user communities. In some cases, programs chose to establish institutionalized and rigorous requirements control mechanisms, and sought to limit severely user feedback loops into the requirements process until after developmental test and evaluation (DT&E).

Crosscutting Cost Analysis Issues

EA Complicates "Truth in Costing"

The Young Panel report placed a strong emphasis on the need to improve the quality and realism of early program cost estimates in national security space programs. The Panel concluded that the "space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the process." This problem in turn "leads to unrealistic budgets and unexecutable programs" (DoD, 2003b, p. 2). In response to the Young Panel findings, NSSAP 03-01 places considerable emphasis on enhanced mechanisms for improved cost estimating in space programs, including formation of independent cost analysis teams (ICATs), and the formal requirement for independent cost assessments (ICAs) or independent cost estimates (ICEs) at various program key decision points (KDPs).[5] The objective of these measures, in the words of one program official interviewed, is to achieve "truth in costing."

The Young Panel Report findings and NSSAP 03-01 have encouraged a high level of sensitivity to cost estimating issues among

[5] For details, see U.S. Department of Defense (2004, Appendix Three).

program managers involved in the case studies examined. In particular, several of the programs examined emphasized that a much stronger effort was being made by program offices to include all ground, user, and support elements, as well as complete life-cycle cost (LCC) factors, in the overall cost estimating process, in order to achieve the goal of full truth in costing.

Unfortunately, many program officials interviewed noted that EA makes the renewed attempts to achieve truth in costing much more complex. The Young Panel noted that in addition to the problems of requirements creep and requirements changes touched on above, several other factors are basic reasons for cost growth on space programs. These factors include contractor buy-in, technological overoptimism among both contractor and program officials, flawed technological maturity assessments, and inadequate assessment of overall program risk. Accurately assessing these issues can become much more complex on an EA program, in the opinion of many officials interviewed. This is, of course, because, by definition, the end requirements in spiral development are not known at the time of program inception. In addition, as noted above, program officials and contractors discovered early on that defining the precise content and structure of specific spirals or increments, an acceptable level of threshold requirements and capabilities for initial increments, and the overall path to the final objective requirements and capabilities, were proving to be challenging tasks indeed. Some program officials observed that the uncertainties and complexities involved in this process greatly increased the difficulties confronted by the cost analysts, and complicated the attempts to maximize truth in costing through the development of higher quality cost estimates.

EA Necessitates Evolutionary or Incremental Cost Estimating

The challenges discussed previously have led program managers and cost analysts to conclude that EA, especially if implemented through the spiral development process, requires the use of evolutionary or incremental cost estimating. In other words, given the uncertainties regarding the detailed content of future increments or spirals, it must be accepted that cost estimates have to evolve and be updated con-

tinuously as the program structure and requirements unfold and mature over time.

This issue, along with other mandated program requirements, has tended to encourage program managers to move away from the spiral development process, where end requirements—even for the initial increment—may not be known at program inception, and toward an incremental development approach where requirements are well defined at program inception, thus simplifying the task of the cost analysts and permitting greater fidelity to the truth in costing concept. The existing statutory, regulatory, and oversight reporting requirements have pushed program managers in this direction. Without firm requirements and a clearly mapped out program structure early in a program—at the very least for the first major increment—programs may appear too open-ended and ill-defined, and thus possibly more subject to the factors identified by the Young Panel as leading to unacceptable cost growth. Such concerns appear to have effectively ended the use of spiral development as originally envisioned in the case studies examined, although acquisition managers insist that the concept had already been modified to apply only *within* specific and well-defined increments with clear and established requirements, rather than across increments.

Focus of Cost Estimating Effort Is on the First Increment

Given the factors discussed previously, the application of EA in many of the programs examined has led to the de facto treatment for costing purposes of the initial program increments or spirals as, in effect, equivalent to stand-alone programs. This is because often only the first increment has achieved the level of detail regarding requirements and other program details that permits application of rigorous bottom-up cost estimating methodologies. With all the programs examined in early concept formulation phases, follow-on increments are defined (if at all) to a level of detail that permits only high-level estimates, which are essentially derived from the long-term program budget plan.

EA Requires More Up-Front Effort and Cost

The program officials interviewed generally agreed that EA requires more up-front planning, work effort, and cost than the old single-step-to-capability approach. Defining and coordinating the structure and content of various increments, planning for the milestone requirements for each increment, assessing and promoting technology insertion opportunities, and the need to develop and update cost estimates on a nearly continuous basis increase workload for cost analysts and program managers. The additional costs for this increased workload must be anticipated and budgeted.

Keeping these crosscutting acquisition management and cost analysis issues in mind, the monograph now briefly reviews and comments on the five principle case studies.

Space Acquisition Case Studies: EA in Practice

SBSS: An EA Strategy for Rapid Fielding of Threshold Capability

Introduction. The SBSS program is a relatively straightforward, lower risk, lower cost, two-stage EA program that grew out of a modest technology demonstration program. The main objective for using an EA strategy on this program was to promote a much more rapid development and fielding of a basic operationally useful threshold capability than originally anticipated to fulfill an urgent and unexpected near-term requirement.

SBSS aims at providing timely detection, identification, and tracking of human-built space objects. Its goal is to enhance space situational awareness and support national defensive and offensive counter space strategies.

The SBSS program emerged as a follow-on to the Midcourse Space Experiment with Space-Based Visible Sensor (MSX/SBV) program, a Ballistic Missile Defense Organization (BMDO)[6] technology demonstrator launched in 1996 to test whether objects in space could

[6] BMDO has now become the Missile Defense Agency, or MDA.

be identified and tracked from a space-based platform. In October 1997, the Air Force Space Command (AFSPC) formally initiated the MSX/SBV as an Advanced Concept Technology Demonstration (ACTD) program; the single space vehicle proved so useful that in 2000 it was incorporated into the Air Force's largely ground-based space surveillance network as a dedicated sensor (Space-Based Space Surveillance Program Office, 2004). At the same time, the SBSS program was initiated to extend and enhance the capabilities that the MSX/SBV had demonstrated.

When the SBSS program began, first launch of an initial system was expected by fiscal year (FY) 2010. Soon after, however, Air Force officials became concerned about the growing probability of catastrophic failure of the SBV, which had already exceeded its design life. In December 2002, the Air Force Requirements Oversight Council called for the fielding of a replacement for the SBV by 2006, four years earlier than originally anticipated.

An EA strategy appeared to be ideally suited to the requirement of rapidly fielding an urgently needed, operationally useful basic threshold replacement capability for the MSX/SBV by 2006 to fulfill the near-term requirement, followed later by a more capable system to meet a more demanding but less urgent objective requirement. To reflect this new EA strategy, the SBSS program was restructured into two increments:

- The SBSS Pathfinder, an SBV replacement intended to provide an interim surveillance capability; and
- The SBSS Objective System, an Acquisition Category (ACAT) IC Major Defense Acquisition Program (MDAP).[7]

SBSS Increment 1: Pathfinder. The primary goal for Increment 1 of the SBSS program is to develop a single space vehicle, the SBSS

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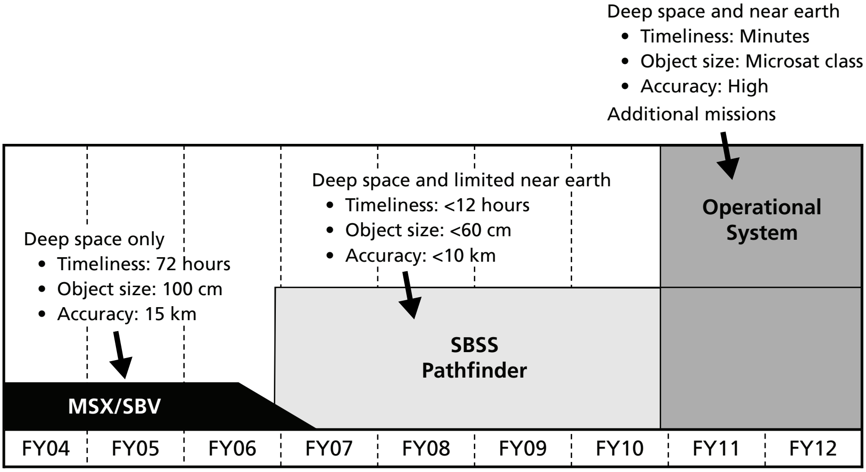
[7] As noted previously, a DoD Space MDAP is an acquisition program that is designated by either the DoD Space Milestone Decision Authority or the Under Secretary of Defense for Acquisition, Technology, and Logistics as being of special interest or requiring an eventual total expenditure for research, development, test, and evaluation (RDT&E) of more than $365 million in FY 2000 constant dollars; or, for procurement, of more than $2.190 billion in FY 2000 constant dollars (Office of the Under Secretary of the Air Force, 2003).

Pathfinder or Block 10 satellite, to replace the SBV. As shown in Figure 2.1, the threshold requirement for the Increment 1 system is simply to replace the existing but threatened SBV capability with a similar although modestly improved capability. Rapid deployment, rather than dramatically improved capability, is the highest priority. First launch had been targeted for June 2007, but in 2005 the launch date was rescheduled for 2008. In late 2004, a $27 million congressional cut to the program's FY 2005 budget forced the SBSS SPO to delay the preliminary design review, which had been scheduled for October. By April 2005, the PDR had been successfully completed (Boeing Company, 2005).

In terms of cost estimation and acquisition management, SBSS Increment 1 is effectively a stand-alone program. FY 2004/2005 Biennial Budget Estimates for the Air Force indicate that the approximate total cost through FY 2009 for the Pathfinder will be in the $800 million range, whereas Increment 2 is expected to be an MDAP (Fernandez, 2004). The prime contractor for the Pathfinder is Northrop Grumman Mission Systems; in March 2004, Northrop awarded Boeing Integrated Defense Systems a $189 million contract to develop and initially operate the Pathfinder (Morris, 2004). A Boeing press release suggested that follow-on work on future SBSS satellites could be in the neighborhood of $2 billion (Singer, 2004).

In addition to rapid provision of an urgently needed threshold capability, the SBSS Increment 1 Pathfinder is intended to provide a proof of concept role and operational feedback for evolving and firming up the requirements for the objective system in Increment 2. The incremental phasing of the program provides the opportunity for feedback of requirements for the objective system, as shown in Figure 2.2. Specifically, SBSS Pathfinder is intended to make the following contributions to Increment 2:

Figure 2.1
Increments, Schedule, and Capability Objectives for the SBSS Program

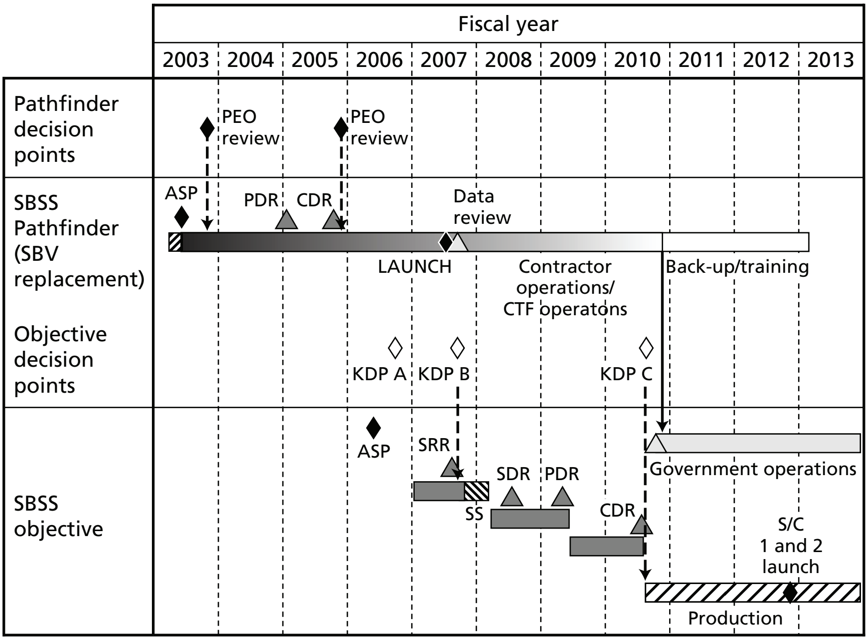


SOURCE: SBSS Program Office (2004).
RAND *MG431-2.1*

- Define the initial command and control interfaces for future space control systems
- Break ground for a new tasking, processing, exploiting, and disseminating architecture
- Serve as a tool for a combined task force to develop initial tactics, techniques, and procedures
- Serve as an on-orbit platform for characterizing visible sensor performance limits.

Given this program structure and these operational and developmental objectives for Increment 1, SBSS can be characterized as using a spiral development implementation strategy (based on the definitions provided by the DoD 5000 guidance documents), since the end requirements for the objective system are not known at program inception, but rather will evolve as experience is gained with the threshold system.

Figure 2.2
Incremental Phasing Allows Feedback from SBSS Pathfinder to Requirements for SBSS Objective System



SOURCE: SBSS Program Office (2004).

NOTES: PEO = program executive office; ASP = Acquistion Strategy Panel; PDR = preliminary design review; CDR = critical design review; CTF = combined task force; KDP = key decision point; SRR = system requirements review; SDR = system design review; SS = space sensor; S/C = spacecraft.

RAND *MG431-2.2*

SBSS Increment 2: The Objective System. Notionally, the SBSS objective system, or Block 20, will consist of a four- to six-satellite constellation in low-earth orbit, and will emerge from the second major program increment. Its broad mission objectives, in order of priority, are to do the following:

- Detect, identify, and track human-built space objects in a timely manner
- Enable global strike task forces to find and track deep-space and near-earth resident space objects

- Support the space surveillance network in maintaining an accurate catalog of all resident space objects (Space-Based Space Surveillance Program Office, 2004).

The more specific objective system requirements for Increment 2 are still uncertain; their evolution will be highly dependent on the Pathfinder experience. Program stretch-outs will provide even more time for feedback from Increment 1 into Increment 2.[8] Initially, Key Decision Point (KDP) A—the point at which the Increment 2 system will move into the concept and architecture development stage—was planned for FY 2006. However, the SPO now expects that the competition to select a prime contractor will begin sometime in FY 2007 (Morris, 2004).

As a result of the spiral development approach being adopted, and the uncertainty regarding Increment 2 requirements, the SBSS SPO emphasized the necessity to engage in evolutionary cost estimating as the program evolves as the only feasible approach to achieving high-quality cost estimates. According to the SPO, the evolutionary costing approach has posed few challenges, and is considered to be functioning well. Since the program is not now an MDAP, and is relatively low-profile, uncertainties over ultimate cost that arise from evolutionary costing do not seem to have provoked any political reactions. This is not true, however, with larger, higher-profile programs, as discussed later in this chapter.

RAIDRS: EA as Potential Foot in the Door?

Introduction. RAIDRS as currently structured is an even more modest, relatively low-cost, low-risk program compared to SBSS. Also like SBSS, the first segment of RAIDRS is in effect structured as,

[8] In July 2004, Congress cut $27 million from the Air Force's SBSS request of $102 million for FY 2005. This cut was reportedly due to congressional frustration over a six-month delay in awarding $189 million to a Boeing-Ball Aerospace team subcontracted to Northrop. According to the SBSS SPO, the contract delay was due to unspecified "launch risks." The SPO claimed that the funding cut could delay the launch (scheduled for 2007), but would not affect program capability. The launch date has now moved to 2008 (Collard-Wexler et al., 2004).

and is being treated as, a stand-alone program. In its current form, RAIDRS is essentially a software and ground equipment integration effort, with no dedicated new SV involved. Unlike SBSS, however, the current RAIDRS program originated from a larger and more ambitious earlier planned version of the program informally known as "Big RAIDRS." On the positive side, EA was adopted for RAIDRS to break the program up into more manageable, lower-risk increments, to provide an earlier operationally useful capability, and to fit the program into current budget realities. Yet some program officials expressed concerns to us that some contractors may view the adoption of an EA strategy as a ploy to keep the Big RAIDRS concept alive during a period of budgetary difficulties and uncertainties over the ultimate objective requirements for the program. A possible negative implication is that EA is being perceived by some as a means to keep a foot in the door for Big RAIDRS, thus potentially leading to the commitment of the government to a program that may end up costing much more than currently projected.

Big RAIDRS floundered in the 2000–2003 time frame because of difficulties over requirements definition and budgetary constraints. Big RAIDRS illustrates some of the budgetary challenges that can be encountered on large, high-visibility programs that adopt a spiral development approach. When final objective requirements remain vague and ill defined (as they will always be at the beginning of a spiral development effort), overall program cost estimation is difficult. In potentially large-scale high-cost programs such as Big RAIDRS, the senior political and service leadership may be uncomfortable with the attendant program cost uncertainties, particularly in light of the Young Panel's strong criticism of historic cost growth on past space programs, and the NSSAP 03-01 emphasis on cost estimating realism. Not surprisingly, then, Big RAIDRS evolved toward EA, and eventually adopted an incremental rather than a spiral development approach, at least in principle. However, the immediate, near-term reason for adopting an EA approach emerged in 2003 when an urgent need arose for very rapid fielding of an initial operationally use-

ful capability. In this sense, RAIDRS Spiral 1 is very similar in origin and structure to SBSS Increment 1.[9] For this type of situation, where rapid deployment of a basic threshold capability is considered urgent, EA strategies appear to be well suited.

The RAIDRS program had been originally conceptualized as a multi-billion dollar program to meet two missions: Defensive Counterspace (DCS) and Space Situational Awareness (SSA). DCS activities consist of "active and passive actions to protect our space-related capabilities from enemy attack or interference," while SSA is the "ability to know the exact whereabouts and actions of Earth-orbiting objects" (U.S. Air Force, 1997, p. 48; 2001, p. 14).

As noted earlier, it proved very difficult to settle on an overall consensus concept for the original Big RAIDRS program—especially for its DCS mission—and after about three years of conceptual development, it did not appear that the necessary budget for achieving it would be forthcoming. But hostile activities against U.S. military satellite communications in early 2002 brought a new level of urgency to the requirement to protect them. Therefore, in 2003, the Big RAIDRS program was restructured in both concept and proposed budget and transformed into a new RAIDRS program with a more limited, but much clearer, near-term threshold objective: to develop and quickly make operational a system that could differentiate hostile attacks on military satellite communications from natural or unintentional events, and enable the timely deployment of defensive responses to counter threats (Rapid Attack Identification, Detection, and Reporting System Program Office, 2004).

RAIDRS Spiral 1: Fast-Track Threshold Capability. RAIDRS program management decided that, given restricted development dollars and the new and pressing need for a rapidly fielded capability, it

[9] Note the technically incorrect use of the term "spiral" to describe the first development element of the RAIDRS program. Several other programs examined appear to apply EA terminology incorrectly, particularly the terms "spiral" and "incremental." Some programs have changed the terminology they use over time. This indicates persistent confusion over the new DoD definitions, or at least a lack of precision in their use. It appears that the trend toward using the term "increment" rather than "spiral" also reflects a general trend away from the formal use of the spiral development approach, as discussed elsewhere in this book.

made sense to recast RAIDRS as an evolutionary acquisition program. Both budget and schedule considerations have led managers to design a RAIDRS Spiral 1 system that does the following:

- Relies heavily on available commercial and government hardware
- Protects only the most vulnerable communication satellites
- Leverages existing space assets.

A formal request for proposals for RAIDRS Spiral 1 was released on October 22, 2004, with a November 2004 deadline for submissions. Like SBSS Increment 1, RAIDRS Spiral 1 is a relatively modest effort. In 2004, RAIDRS program managers estimated that the budget for RAIDRS Spiral 1 will come to roughly $15 million per year in FY 2005 and 2006, rising to approximately $35 million at IOC in FY 2007.[10] In total, RAIDRS was expected to cost about $136 million through full operational capability (FOC), which was targeted for FY 2009. To control costs, the Spiral 1 system hardware will be acquired as commercial off-the-shelf (COTS), government off-the-shelf (GOTS), or build-to-print, with roughly 50 percent of the hardware expected to be COTS. Much of the RAIDRS Spiral 1 effort is devoted to developing software that will allow ground controllers to manipulate and interpret data downloaded from satellites.

RAIDRS' focus at Spiral 1 initial operational capability (IOC) will be on the Defense Satellite Communications System (DSCS). Focusing on DSCS will also allow RAIDRS to leverage capabilities provided by the U.S. Army's interference monitoring power control subsystem (IMPCS), which already monitors DSCS for electromagnetic interference, but can only determine the source of the interference after communications have been processed.[11] RAIDRS will use information provided by IMPCS to geolocate the source of interfer-

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[10] Congress approved an FY 2005 budget of $16.4 million for RAIDRS in July 2004.

[11] IMPCS does not distinguish between interference due to hostile attacks versus natural events. The Army uses it simply to reallocate bandwidth away from satellites experiencing interference.

ence in transponded communications and report it to the Air Force in near real time. One suite of equipment (a single interference detection system [IDS] unit plus a geolocation unit) will be required to achieve these initial capabilities.

At FOC, RAIDRS Spiral 1 is projected to have more units than at IOC—perhaps as many as eight geolocation units, 36 interference detection system units, and a laser dazzling detection unit. These additional units will allow it to monitor all critical communications worldwide, detect electromagnetic interference with satellite communications and laser dazzling of Defense Support Program (DSP) early-warning system satellites, geolocate attackers, and report the event to the designated Air Force Operations Center (AOC) for space. FOC for the objective requirement for Spiral 1 is planned for FY 2009, but this will be driven more by budgetary than by technological considerations because the added capabilities of the objective system mostly do not involve development of new technology.

In May 2005, the Air Force awarded the RAIDRS Spiral 1 contract to Integral Systems, a major provider of satellite ground systems. As prime contractor, Integral Systems teamed with numerous other contractors, including Intelsat, Northrop Grumman, and QinetiQ. The contract was for the relatively modest amount of $123 million over five years. Integral Systems' technical proposal relies heavily on COTS equipment. Earlier, Integral Systems also won a study contract to investigate concepts and technologies further for RAIDRS Spiral 2 (Integral Systems, 2005).

RAIDRS Spiral 2: Keeping the Door Open for Big RAIDRS? Because the Spiral 1 system will have only a command and control function (allowing users to geolocate the source of electromagnetic interference but not to assess the nature of the threat), one concept for follow-on spirals, if they are undertaken, is the development of a decision support element. This element would be able to read information provided by the RAIDRS interference detection and geolocation systems and automatically combine it with data from intelligence and other databases to assess the seriousness of the threat. Alternatively, future spirals could simply involve an increase in the number of units developed in Spiral 1. Yet through most of 2004, the requirement

and even the concept of a possible Spiral 2 remained largely unknown.

As of late 2004, there was little funding available to support additional concept definition or requirements development for RAIDRS Spiral 2. Furthermore, the compressed Spiral 1 schedule permits only limited feedback from Spiral 1 into the requirements generation process for follow-on spirals. In 2004, the SPO began to prepare program research and development documents (PRDAs) for Spiral 2, and requested industry feedback on a statement of objectives for Spiral 2 by October 6, 2004. At that time, the SPO expected to spend between $5 million and $10 million by FY 2007 to refine system requirements for Spiral 2. It hopes to achieve KDP B (approval of concept development) for Spiral 2 by FY 2008. In late 2004, however, this budget and schedule continued to be largely notional. Thus, in effect, RAIDRS Spiral 1 remained essentially a stand-alone program. During FY 2004, nearly all of the requirements documents, trade studies, and cost estimates continued to focus on Spiral 1.

During 2004, SPO officials believed it was quite possible that Spiral 1 would conclude the RAIDRS program: The contracts for Spirals 1 and 2 are entirely separate, and it is not clear that contractors' work experience and success on Spiral 1 will necessarily increase the probability of winning contracts for Spiral 2. As noted previously, Integral Systems was also awarded a Spiral 2 study contract. The initial funding, however, was very small. The February 2005 Air Force budget justification projected expenditure of only $5.7 million through FY 2006 on Spiral 2 concept definition and pre-acquisition architecture and system development. This number was projected to rise by $7.1 million in FY 2007 (U.S. Department of the Air Force, 2005, p. 962).

According to the SPO, at least some contractors apparently believe that Spiral 1 could be an entrée to a much larger reborn Big RAIDRS program in the future. RAIDRS Spiral 1 program managers raised some concerns that, to the extent contractors are correct, any such Big RAIDRS program may be susceptible to requirements creep, a problem that bedeviled the original Big RAIDRS program. In the view of some program officials, acquisition reform measures have

transferred so much influence over system specifications to contractors, that in a program with ill-defined requirements, requirements creep may become a significant challenge.

Finally, with respect to the program cost analysis effort, the costing of RAIDRS Spiral 1 and Spiral 2 has also been kept entirely separate. While the costing of Spiral 1 certainly involves challenges, its boundaries are fairly well defined, because the requirement is reasonably clear and unambiguous. Even for Spiral 1, the SPO has engaged in an evolutionary costing effort as the content of the spiral has evolved. The situation is totally different for Spiral 2, however. With no system concept, concept of operations, or objective requirements clearly defined, it is simply not possible, in the view of the SPO, to do any sort of meaningful cost estimates for the Spiral 2 system. This has led some observers to question whether RAIDRS Spiral 1 might be viewed as a low-ball buy-in that masks a commitment to a much larger program. As of late 2004, the relevance of such a criticism could not be assessed, but clearly the SPO expressed concerns that at least some contractors might view the program this way.

GPS III: Prudent Incrementalism or a Foot in the Door?

Introduction. Unlike the previous two systems, Global Positioning Satellite (GPS) III is a follow-on program to a well-established and highly successful existing program. Nonetheless, GPS III is a very ambitious large-scale space acquisition program envisioning major investments in the development and procurement of a series of totally new space vehicles (SVs), ground control hardware, and receiver units. The Air Force expects to commit $830 million to the GPS III program through FY 2011, with first launch of a new SV expected in FY 2013 (U.S. Department of the Air Force, 2005, p. 619). In 2004, GPS III was still in a very early system definition stage. Program managers initiated plans for a long, potentially rather complex multiphase EA approach that notionally aimed at achieving an initial launch capability (ILC) in FY 2012 to attain a threshold capability. At least four notional spirals (called Increments A–D) were

under consideration and being assessed in 2004.[12] The initial increment (Increment A) was intended to meet a threshold capability, while Increment D was aimed at achieving the objective system capability.

The GPS system of course has been in place for decades. The existing NAVSTAR Global Positioning System dates back originally to the 1970s. Currently, it is made up of a 24-satellite constellation providing 24-hour navigation and timing information to military and civilian users worldwide. GPS satellites, in one of six medium earth orbits, circle the earth every 12 hours emitting continuous navigation signals on two L-band frequencies, L1 and L2. In addition to the space segment, the GPS system consists of a worldwide satellite control network (the control segment) and GPS receiver units (the user segment) that acquire the satellite's signals and translate them into precise position and timing information.

There have been five major block upgrades to the GPS space segment since its initial launch during the 1970s: Block II, Block IIA, Block IIR, Block IIR-M, and Block II-F. In 1997, Block IIRs began replacing Block II and IIAs, offering a precise positioning service on L1 and L2 and 20 MHz bandwidth. The launch of the first Block IIR-M, offering a second civil signal on L2 plus a new military-code signal on L1 and L2, took place in September 2005. The next upgrade of GPS, the Block II-F, providing a third civil-only signal on L5 and boasting a longer design life than previous models, is scheduled to launch in 2007.

According to officials within the GPS III Joint Program Office (JPO), each of the GPS Block II upgrades has involved mainly software changes combined with relatively modest changes to system hardware, in part, because the primary objective requirement for GPS II, improved accuracy, has remained the same over time. Further, all of the Block II satellites have essentially been passive, transmitting their signals indiscriminately and without charge to all users.

[12] Once again, note the mixing and incorrect use of terms "spirals" and "increments," which, technically speaking, violates the definitions in the DoD 5000 series guidance.

The vision for GPS III is quite different, involving a broad range of possible new missions and new objective end capabilities for the overall system. Most important among the new military capabilities envisioned are much more robust navigational warfare (NAVWAR) capabilities,[13] significantly improved accuracy, near real-time constellation management, and signal flexibility and reprogrammability. These in turn require the progressive development and upgrading of a series of entirely new space vehicles (SVs) and ground support hardware, along with new software. For these reasons, program managers argue, acquisition of the GPS III system is particularly well suited to an evolutionary approach. As noted previously, the GPS III program, as of late 2004, notionally consisted of four developmental spirals, culminating in the objective system.

GPS III Spiral 1: Meeting Threshold Requirements. As of mid-2004, GPS III Spiral 1 had already evolved considerably in its planning and structural maturity. Spiral 1 was expected to add the following broad capabilities to those already existing on the GPS II-F variant:

- A dual-launch capability
- A satellite vehicle bus designed for future technology insertion
- Improved accuracy
- Some ability to deny access to enemies
- Increased signal flexibility and jam resistance.

As of 2004, program funding requirements were put at $2.1 billion through FY 2009; the development contract was scheduled to be awarded in 2006, with initial launch capability (ILC) expected in FY 2012. Both the budget and schedule may still undergo significant changes, however, as Spiral 1 is still in acquisition Phase A, the con-

[13] A key aspect of the improved NAVWAR capability is based on the spot beam concept that is intended to permit around-the-clock military operations in heavily jammed environments with no mobility constraints.

cept development phase.[14] The final product of this phase will be a system specification for a satellite bus to be developed by contractors in Phase B.

In a significant departure from previous GPS programs, a key feature of the evolutionary GPS III program is that GPS III Spiral I involves parallel and harmonized development of the user equipment and ground control segments. In fact, both the capability development document (CDD) and concept of operations (CONOPS) document for GPS III explicitly require complete ground segment control functionality by the end of Spiral 1. According to program managers, the strictness of this phasing requirement is due to past problems with space acquisition programs, where the ground control segment development was not adequately coordinated with the SV element, thus blocking the ability to take full advantage of space segment capability after ILC.

GPS III Future Spirals: Defining a Path to Objective Capability. The GPS III program is in its very earliest concept development and planning stages. The JPO has adopted a competitive approach with multiple contractors to maturing GPS III requirements for a formal system requirements review (SRR) in 2005 and to support the KDP B review. A full and open competition to award a single GPS III development contract is planned for FY 2006 to support the SDR. The draft CDD for GPS III identifies the threshold and objective requirements for the full system. As of early 2005, the SDR and KDP-B were planned for 2007 (U.S. Department of the Air Force, 2005, p. 624).

The Spiral 1 system, of course, is being designed to meet the threshold requirements. However, as of 2004, development of CDDs for follow-on spirals, which will define the path to objective capability, are not planned for another three to four years. Two competing contractors (Boeing and Lockheed) are generating their own unique company-specific content for potential paths to objective capability. Individual steps along the path were originally defined in terms of

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[14] According to GPS III program managers, Phase A was initiated in FY 2000, but has been disrupted three times due to budget instability.

technical requirements, but they were later redefined in terms of capabilities, leaving the determination of the technical means of achieving those capabilities to the contractors. As of mid-2004, very large uncertainties remained regarding the final structuring and technical content of the follow-on phases, and the precise path to full objective capabilities.

Cost estimating on the GPS III program is being approached in much the same way as on the RAIDRS (and SBSS) program: Spiral 1 is being costed through FY 2011, based on the evolving threshold requirements, while future spirals will be costed as entirely separate programs. Yet, as of mid-2004, so few specifics had been worked out regarding follow-on EA phases that no meaningful costing effort was possible beyond Spiral 1. Therefore, as with RAIDRS, there have been questions raised in some quarters as to whether the GPS III acquisition strategy represents wise incrementalism, or, rather, could be characterized as a foot in the door for a much larger program that has not yet been openly acknowledged. Yet the GPS III program has provoked relatively little controversy, in part because of the long historical track record of success for GPS, and because of the widespread, incorrect impression that GPS III merely represents another series of block upgrades on the same pattern as the current GPS II system.

SBR: A Large, Complex, High-Profile EA Program

Introduction. The Space-Based Radar (SBR) is a much larger, more complex, and higher profile EA program than the others reviewed here.[15] It envisions developing a range of far-reaching and very ambitious space-based surveillance capabilities to serve multiple user communities. It is a potentially very demanding program, both technologically and organizationally, which must satisfy the diverse needs and preferences of many very different user communities. Because of these characteristics, major challenges in the early phases of the program have included the issues of defining both threshold and objective requirements and capabilities (both for the overall program

[15] The SBR program was restructured in 2005 and renamed the Space Radar (SR) program.

and within increments); selecting the appropriate technologies and capabilities, and the phasing of their insertion; and the structuring of the program EA increments and the precise path to the objective end capabilities of the system. In addition, considerable debate and discussion have surrounded the question of the cost effectiveness of the capabilities provided by program, the credibility of various official and unofficial cost estimates of the program, and the budgetary phasing of the effort.

The SBR program began in 2001 following the cancellation of the Discoverer II program by Congress due to concerns over cost, schedule risk, and uncertainty over requirements. During its relatively brief tenure in its original form (from 2001 to 2005), SBR also experienced considerable controversy over similar issues that was reflected in major funding instabilities. For the purposes of this monograph, however, the authors primarily focus on only one aspect of the program: how program officials attempted to apply EA concepts to the SBR acquisition approach to help reduce cost and technological risk and achieve a more rapid fielding of an operationally useful capability. The SBR experience suggests that in such a complex and high-profile program as this, the successful application of a coherent EA strategy is enormously challenging. Nonetheless, despite many bumps in the road, senior DoD Space leadership has continued to support SBR and is heavily committed to using a form of EA to move the program forward while controlling risks and costs. One could even argue that the program restructuring into a technology demonstration effort in 2005 represented a legitimate attempt to apply EA concepts more rigorously to a large and complex developmental effort.

As noted previously, the SBR program grew out of Discoverer II, a joint Air Force, Defense Advanced Research Projects Agency (DARPA), and National Reconnaissance Office (NRO) technology demonstration project that was intended to improve the coverage and timeliness of space-based reconnaissance and surveillance. Congress canceled Discoverer II in 2000, but approved $30 million for the NRO to continue further technical development for the space-based radar concept. According to press accounts, Congress cancelled Discoverer II because of "uncertain costs and schedule, poorly explained

requirements, and a lack of coherent vision for how the system would transition to operational use" (Tirpak, 2002, p. 64). Similar criticisms would continue to dog the follow-on SBR program effort.

When the Air Force became the executive agent for military space activities in 2001, it took over leadership of the joint Air Force–NRO program. The SBR program was initiated in November 2001 to provide military forces with the capability to find, identify, track, and monitor moving targets on the ground from space. The central mission for SBR was extremely demanding: to provide persistent global surveillance and global situational awareness using advanced technologies for surface moving target indication (SMTI), synthetic aperture radar (SAR) imaging, and high resolution terrain information (HRTI).

One of the most challenging aspects of the SBR program was the need to harmonize military and intelligence requirements for processing and disseminating data on both mobile and stationary targets from around the globe to multiple diverse user communities with sometimes differing objectives. As one observer wryly noted, with perhaps a bit of exaggeration, there were somewhere between "fifteen and eighteen customers who all want different things" from the SBR system. Daily management of the program was complicated by the existence of a JPO that represented a range of organizations, both inside and outside of the Air Force, which were often advancing varying and sometimes conflicting agendas. Inside the Air Force and on the acquisition side, these included both the Space and Missile Systems Center (SMC), and the Electronic Systems Center—with the latter focusing on SBR program aspects related to Battlefield Management and Command, Control, and Communications (BMC3). Other major players at the SBR JPO include the NRO, the Army, the Navy, and the National Geospatial Intelligence Agency (NGA).

In the early days of the program, disagreements among various potential stakeholders and user groups regarding mission priorities led to disputes over fundamental system architectural issues and program phasing. For example, if greatest priority is placed on achieving an early high capability in wide-area SMTI, then a higher altitude constellation (medium earth orbit or MEO constellation) of SVs with

lower resolution capabilities would be selected as the first priority. However, if the greatest emphasis is placed on the intelligence gathering missions aimed at fixed installations, then preference might shift to a lower altitude constellation (low earth orbit or LEO constellation) with higher resolution capabilities. The selection of one architecture over another has enormous implications for the number of SVs that might need to be procured, the type of SVs, and the overall cost of the program. Since the senior DoD leadership determined early in the program that only one overall system was affordable for both intelligence and warfighting purposes, SBR had to be a compromise system that met both the intelligence and warfighting communities' requirements, and thus had to contain both MEO and LEO elements. However, the exact mix was obviously open to debate.

In addition to these types of difficult challenges regarding the definition of system architectures, capabilities, and requirements for multiple users and arbitrating among legitimately differing needs, the SBR program was also complicated by the advocacy of alternative technical solutions and architectures, and by organizational turf wars over which entity would act as the ultimate control authority for the overall system and its requirements. Here again, the most challenging issues arose from the differing perspectives of the intelligence and operational warfighting communities. In addition, considerable discussion also emerged over the optimal mix between and integration among space-based, land-based, and air breathing assets such as Joint Surveillance Target Attack Radar System (JSTARS) and unmanned aerial vehicles (UAVs) platforms.

Finally, to complicate program management and cost estimation efforts further, the program was increasingly subjected to intense and sometimes hostile public scrutiny and skepticism from Congress and other outside observers, for a variety of reasons. There is no denying that, no matter how it is defined, SBR was likely to be a very expensive program. As of early 2005, program costs at the very minimum were officially projected at $28 billion through FY 2024 (Rees, 2005). Early in the life of the program, some estimates as high as $68 billion for some types of possible architectures were circulated in the defense press and in the halls of Congress. Much lower independent

cost estimates in the range of $34 billion in FY 2004 dollars were produced by the DoD Cost Analysis Improvement Group (CAIG) and by the Program Office.[16] Nonetheless, even the lower estimates meant that SBR would be one of the largest and costliest space programs ever in the Air Force portfolio. In the wake of the Young Panel findings and the severe criticisms of large cost overruns and poor cost estimating track records on such programs as the Space-Based Infrared System High (SBIRS High) and other space acquisition efforts, it is not surprising that SBR was increasingly subjected to a healthy dose of scrutiny and skepticism.[17]

The SBR JPO implemented numerous management initiatives in response to these circumstances. To ensure requirements harmonization among the diverse user communities, and to control requirements creep and unwarranted cost growth, the SBR program office established three senior-level requirements oversight groups consisting of senior officials from OSD, the military services, and the intelligence community. Each of these groups was responsible for advising the joint program office on the acceptability of various cost, schedule, and performance tradeoffs. Another major initiative was an extensive

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[16] The SBR JPO argued that the high estimates were utterly flawed because they were not founded on the official baseline assumptions established by DoD. Some critics in Congress and elsewhere, however, were skeptical of the CAIG and JPO estimates. The 2004 House Appropriations Committee defense budget report claimed that the lower number was only a "50th percentile" estimate conducted prior to the concept definition phase, and thus should be treated as optimistic. The committee report also alleged that the CAIG estimate did not take into account a full "objective SBR constellation of 21–24 satellites," the total costs of which "*could exceed $60 billion* based on the current understanding of program requirements and technology" (U.S. House of Representatives, 2004, p. 313, italics in original). The authors of this RAND monograph have not attempted to assess independently the accuracy of any of these estimates, but merely report the range of estimates that was being debated publicly at the time. See also "Appropriators Slash Space-Based Radar Funding" (2004).

[17] SBIRS High, which originally got under way in the mid-1990s with very high expectations as an acquisition lead pilot program, ended up experiencing significant cost growth and schedule slippage. Just as SBR was standing up, the Air Force announced the need to pour additional money into SBIRS, and even examined the possibility of procuring alternative systems. Congress reacted adversely toward space programs in general when confronted with the need to authorize even more money for SBIRS (Butler, 2004a). For a brief review of the early history of SBIRS as an acquisition reform program, see Lorell and Graser (2001).

truth in costing effort to reduce the chances of contractor buy-in or "low-ball" estimates. More on this approach is described below.

Given the range of challenges discussed previously confronting the program, particularly the difficulties of achieving consensus over the overall objective system requirements and the specific technologies to employ, it appeared to program managers early on that an EA strategy using a spiral development process would be a possible solution to many of the challenges confronted by the program. On the face of it, the SBR program was tailor-made for use of a spiral development implementation strategy, since such a strategy is designed for managing a program with uncertain end requirements and uncertain projections of future technology maturity in key areas. In addition, a central acquisition goal of the SBR program had always been the rapid fielding of an operationally useful threshold system that was as affordable as possible—another major objective of EA.

Thus, to achieve its goals in the challenging circumstances confronting SBR, program managers adopted an evolutionary approach to acquisition of the SBR system, which involved fielding an operationally useful Increment 1 system as soon as possible while deferring all nonessential technologies and capabilities to later increments. As well as speeding up the fielding of the system, program managers believed this approach allowed them to minimize life-cycle costs by waiting until certain technologies were more mature, and therefore less risky and less likely to promote cost growth, before inserting them. Thus a key element of their strategy was to invest in a robust system infrastructure that would be able to support new capability-enhancing technologies if and when they were developed. The program office reasoned that extra up-front investments in technology maturation, as well as in nonrecurring hardware development to make it more upgradeable later as the technologies matured, could pay off handsomely in overall reduced program LCC.

Unfortunately, the JPO's experience to date with this approach has been decidedly mixed. This is primarily because the current regulatory, statutory, and political environments make implementation of a true spiral approach on a high-profile program such as SBR extremely difficult. The pressures placed on cost analysts and pro-

gram managers to generate detailed technical descriptions and cost estimates for the Increment 1 objective system made it nearly impossible to apply the spiral development process to the initial increment.

SBR Increment 1: Difficult Choices. As noted previously, SBR is potentially a very large and costly program, which led to considerable controversy. In 2004, the DoD CAIG estimated that, if *all* costs associated with Increment 1 were included, the total could well reach $35 billion through 2025. According to the JPO, one reason that both the CAIG and the SBR JPO estimates were so large is because the JPO, in response to the Young Panel recommendations and NSSAP 03-01, adopted a rigorous truth in costing approach that includes a wide variety of cost factors routinely excluded in the cost estimates for other programs. For example, the JPO estimates include costs associated with integration, assembly, and testing for all of the 105 different nodes to which SBR was expected to direct information, as well as costs associated with a reference architecture (for initial costing purposes) that consisted of a notional 9 to 10 satellite medium earth orbit (MEO) constellation plus 13 replenishment SVs.[18] The cost estimates also include many other categories of costs that were not typically included in any space acquisition programs, such as costs associated with housing of ground systems personnel.[19]

The JPO's original concept of Increment 1 followed the spiral development approach based on extensive trade studies, experimentation, and feedback loops that would lead to an evolution of the final Increment 1 concept and objective end requirements as the program progressed. Using a notional Increment 1 plan of 9 to 10 SVs plus 13 replenishment SVs as a planning example, the JPO concept proposed a strategy of upgrading the SVs in blocks throughout Increment 1 as the technologies matured and the requirements were refined. Thus a

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[18] In July 2005, the government adopted an official baseline for the program called the Space Radar Government Reference Architecture (GRA). The GRA consists of a nine-satellite, low, earth-orbit constellation.

[19] As noted previously, critics in Congress and elsewhere were skeptical of the cost estimates produced by the JPO and the CAIG during this time frame and criticized some of the notions underlying the baseline assumptions from which the cost estimates were derived.

stair-step spiral approach on hardware and software was advocated in order to build up to a notional IOC for Increment 1 of roughly four SVs. Future improvements during Increment 1 would build on this basic capability with upgraded hardware, eventually producing a notional constellation of 8 to 14 SVs to meet the threshold Increment 1 requirement. As noted previously, an official GRA baseline was established in July 2005 that consisted of a nine-satellite, low, earth-orbit constellation.

The JPO cautioned that much more money would have to be invested up front than in the past to define end capabilities, flesh out notional spirals, conduct ongoing technology maturity assessments, and design and engineer the initial SVs to facilitate later technology insertion. JPO cost estimates included six to seven percent more in additional nonrecurring engineering costs to develop more robust buses and SVs to facilitate the later incorporation of block upgrades. Some nonrecurring funding was also included for beginning development of Increment 2 capabilities during Increment 1. The JPO estimated that this additional up-front expense could save up to 30 percent in nonrecurring engineering costs later in the program when technology matured and technology insertions and block upgrades were made later in Increment 1. This approach was combined with an incremental capability growth plan based on what the JPO called preplanned decision opportunity technology on- and off-ramps, where decisions about major system upgrades and technology insertions could be made based on technology maturity, experience with the existing SVs through feedback loops, and other factors.

For developing the actual as opposed to notional content of Increment 1, the original SBR Phase A acquisition strategy envisioned competing two contractors to refine multiple alternative Increment A concepts during 2004. Each contractor would then mature and select a single preferred Increment 1 concept in support of a formal system requirements review (SRR) and system design review (SDR) in early 2005, with a final down select to one contractor in 2006. In support of this approach, the JPO awarded both Lockheed Martin and Northrop Grumman two-year, $220 million concept development contracts in April 2004.

The JPO was not granted the resources to implement this strategy, however. Shortly after the contract award, the House Appropriations Committee gutted SBR by cutting over 75 percent of the administration's requested funding for FY 2005.[20] The committee's report claimed the program was too risky technologically, too costly, and not likely to achieve the needed capabilities at the projected cost. It concluded that "[w]ithout a new approach, the committee sees little future for the Space Based Radar." Shortly thereafter, the Senate Appropriations Committee also recommended a major cut in the program.[21] Although DoD and the Air Force fought to restore funding, the final conference report filed at the end of July retained the large cuts recommended by the House Appropriations Committee, dealing a blow to SBR characterized by the defense press as "crippling" or "fatal" (Butler, 2004b). The conference report ordered the Air Force to end SBR as a formal acquisition program, and use the remaining $75 million in funding for technology demonstration, risk reduction, and concept development (Butler, 2004c).

In early 2005, press accounts reported that DoD and the Air Force would propose a revised SBR effort that would restructure the first phase of the program into what amounted essentially to an extended technology demonstration and concept development effort. Air Force Under Secretary Peter Teets noted that Congress had to be presented with "a clearer, more affordable path forward" for SBR (Rees, 2005). Central to the effort would be the development of a more detailed concept of operations (CONOPS), which then could lead to the launch of a single demonstration satellite in the 2008–2010 time frame. Concept and CONOPS development would focus on more effectively defining and integrating the requirements of the warfighter and intelligence communities, the two major system users. Following the conclusion of a successful multiyear demonstration

[20] Nearly $253 million were cut from the requested $327.7 million ("Appropriators Slash Space-Based Radar Funding, Criticize Costs," 2004).

[21] The Senate version cut $100 million from the requested $327.7 million (Tuttle, 2004). The final program cut settled on by Congress was $252.7 million, leaving only $73.8 million remaining of the original FY 2005 request (U.S. Department of the Air Force, 2005, p. 749).

program with a single satellite, a new SBR program could be launched that is aimed at the acquisition of a full constellation of operational SVs.

Formal submission of the restructured program to Congress took place in February 2005. To underline the extent of the program restructuring, the program was renamed the Space Radar (SR). The SR program is essentially a concept development and technology demonstration effort, but remains a large-scale program. The central goal of the restructured SR program was to increase the near-term program focus on technology risk reduction, more precise requirements definition, and technology demonstration. Special areas of emphasis for risk reduction efforts included the electronically scanned array (ESA) and on-board processing. Technology risk reduction efforts were envisioned to climax with on-orbit demonstrations. Despite the dramatic congressional funding cuts mandated by Congress for FY 2005, the restructured SR effort proposed by the Air Force envisions a rapid spool-up of funding in the out years. Air Force planners projected spending to rise to over $1 billion in FY 2009, and to increase to over $1.4 billion in FY 2011. Air Force budget documents projected total spending on the program (SBR plus SR) of nearly $5.2 billion through FY 2011 (U.S. Department of the Air Force, 2005, pp. 749, 751–752).

SBR and EA. The SBR JPO originally adopted an EA approach to help manage a very large and complex program with multiple stakeholders, where achievement of consensus on threshold and objective requirements, CONOPS, system architecture, technology maturity and risk, technology insertion and phasing, and a variety of other key program variables was difficult to achieve. In principle, an EA strategy employing spiral development appears to be a sensible strategy to adopt in such challenging circumstances. Time and experimentation were clearly needed to evolve the program forward and clarify a variety of key issues. So what went wrong with the original SBR effort?

According to program managers, the existing statutory, regulatory, and budgetary environments make implementation of a spiral development approach on a large, high-profile program such as SBR

extremely challenging. Particularly when a program is under close scrutiny from Congress, budget planners and cost analysts tend to press for a level of certainty and detail for the entire Increment 1 program that violates the Spiral Development concept. While admitting that the program may have been "overly ambitious" in its early claims, and might have been more clearly defined at the beginning, program managers complained that the budget planners and cost analysts insisted on having precise definitions of what the system hardware and software would look like ten years out. In a like manner, requirements managers tended to proliferate key design parameters very early in the program. The result, in the view of some JPO managers, was that all the program flexibility and positive uncertainties that are inherent in a spiral development approach were constantly under attack from the earliest phases of the program.

The EA process, particularly using spiral development, presumes a high degree of flexibility in budgeting, cost, and requirements, particularly early in the program. According to JPO managers, the current acquisition process does not permit such an approach. Indeed, SBR rapidly evolved from a spiral development program to an incremental development program, then to something approaching a traditionally structured single-step-to-capability program with internal steps or block upgrades. Once it became more like a traditionally structured program, its uncertainties became major deficits that opened it to criticism from many quarters.

It may be that a spiral development approach was not feasible on any potentially large-scale, high-profile program such as SBR, particularly in a difficult political environment such as existed at the beginning of SBR, which was dominated by the specter of large cost overruns and schedule slippage with major space programs such as SBIRS. As General Lance Lord, Commander of Air Force Space Command, noted, "We set the [SBR program] structure up so that we could do technology and risk reduction and have a good contractor team together with the CONOPS [development]." The problem, according to General Lord, was that "some people were taking what's happened in the SBIRS program and saying, 'Okay, if that's the cost

growth you got in that, then you know what [is going on] in other programs'" (Tuttle, 2004, p. 5).

At the time of the original congressional cuts, some senior Air Force officials began publicly questioning whether the spiral development approach should be used on any large-scale hardware development programs. For example, in July 2004, Air Force Major General William Shelton, U.S. Strategic Command's policy, resources, and requirements director, publicly cautioned against the overuse and misapplication of spiral development in space programs. General Shelton argued that spiral development was applicable to software development, but cautioned against its use on expensive, relatively small, specialized space constellations such as SBR: "You really have to think through spiral development for smaller constellations" ("Spiral Out of Control?" 2004). Under Secretary Teets probably put his finger on the key problem with the use of spiral development on programs such as SBR when he noted in early 2005, "I think one of the things last year that kind of got us in a little trouble in terms of getting the program properly funded from Congress is that we didn't define clearly the size and scope of the Space-Based Radar program that we were proposing" (Rees, 2005). Thus, the very flexibility program managers were seeking to provide the tools to resolve uncertainties opened up the program to criticism and skepticism. In short, what may appear to be prudent flexibility and sensible openness to evolutionary change to program managers may appear as open-ended and undisciplined buy-ins by some members of Congress and other observers.[22]

Is evolutionary acquisition, then, not usable on such programs as SBR? The answer is probably not, if the program is heavily dependent on relatively new and immature technologies, and continuing debate exists over system concepts, CONOPS, architectures, requirements,

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[22] Of course, another major area of concern of critics of SBR was the actual level of maturity of the technologies that were planned for near-term insertion into the system. In July 2004, the GAO issued a report to Congress on SBR that strongly recommended that DoD delay the product development stage of SBR to permit fuller assessment, risk reduction, and maturation of the key technologies involved in SBR. This, of course, is precisely what eventually happened (U.S. Government Accountability Office, 2004).

capabilities, technologies, and cost effectiveness. Remember, a fundamental component of EA, at least in the minds of many early advocates, was that each spiral or increment should focus on using reasonably mature technologies to take small steps toward a modest new level of operationally useful capabilities. In the minds of some of its opponents, SBR was planning on drawing on too many high-risk, lower-maturity technologies, even in the early stages of its first increment. In their view, SBR Increment 1 had already evolved into a huge and technologically risky advance in capabilities, thus violating the EA concept of small incremental improvements.

EA using spiral development may be more feasible, however, in a variety of other circumstances. One, of course, may be in technology demonstration programs. Clearly the Air Force has adopted a posture of restructuring the initial phase of a new SR effort as a technology demonstrator effort. If this leads to the successful launch of a new acquisition program, based on more mature technologies and more precisely defined objective system capabilities, then one could argue that this first phase is a form of spiral development, and that the process works.

Other areas where this approach may still be used successfully on large, high-visibility programs are in environments outside the normal DoD acquisition regulatory and statutory environment. The KEI effort may be one such program.

KEI: Capability-Based EA in an Acquisition Reform Environment

Introduction. The KEI (Kinetic Energy Interceptor) missile defense program was initiated in 2002 by the Missile Defense Agency (MDA). The goal of the program is to design, develop, and deploy mobile, kinetic energy–based missiles that can intercept and destroy enemy ballistic missiles. Initially, the KEI was intended to intercept missiles during their boost phase, which can last as little as 180 seconds (Barnard, 2004). Now, however, it is seen as the basis for a multipurpose interceptor that can also destroy missiles in their ascent phase (500–600 seconds after launch) and midcourse phase (including the apex of flight at about 1,200 seconds after launch). Current efforts focus on a ground-based system, but eventually the KEI is ex-

pected to perform boost-phase intercepts from sea-based and perhaps space-based launch platforms. According to a draft environmental assessment issued in September 2004, MDA "contemplates the development of a space-based test bed" in 2012 ("Missile Defense Agency Eyeing Space-Based Interceptor Test Bed by 2012," 2004).

KEI differs from the programs discussed previously in this chapter in at least three important respects. First, and perhaps most important, KEI is being developed by MDA, which is a separate DoD agency that operates in accordance with its own unique acquisition environment. In May 1993, the Strategic Defense Initiative Organization (SDIO), founded during the Reagan administration, was recast as the Ballistic Missile Defense Organization (BMDO), and was restructured to report directly to the Under Secretary of Defense for Acquisition. Almost a decade later, the organization's unique position was further enhanced when Secretary of Defense Donald Rumsfeld upgraded the status of the organization to that of a DoD agency and renamed it the Missile Defense Agency (MDA). MDA is chartered by the President and mandated by Congress. MDA acquisition programs are subject to the normal DoD 5000 regulatory guidance, rather than NSSAP 03-01. However, as a DoD agency with a unique status, MDA program managers can often waive acquisition directives issued as part of the DoD 5000 series. This often permits far more flexibility in the formulation and execution of acquisition strategies than is typical within the normal service acquisition organizations.

Second, by definition and by charter, all MDA acquisition programs are aimed at contributing to the achievement of a single, well-defined, relatively narrow mission objective: "to develop, test and prepare for deployment of a missile defense system" (Missile Defense Agency, undated). The fundamental underlying technology has already been determined. MDA has decided that component missile defense systems will be "primarily based on hit-to-kill technology" (Missile Defense Agency, undated). In addition, MDA operates with a single chain of command, with clear lines of authority. The MDA Director is the acquisition executive for all Ballistic Missile Defense

systems and programs.[23] All specific systems under development are meant to fit into a larger system of systems that contributes to the single overarching mission of MDA. Specific component systems and funding can be traded off against one another by the director and senior MDA management to best achieve the overall MDA mission. Thus, in contrast to SBR and some other space programs, MDA acquisition programs are executed in a highly flexible procurement environment, with a reasonably clearly defined consensus mission requirement, agreement on the basic technological approach, and under a single chain of command with clear lines of authority.

Finally, the director of the KEI program, Terry Little, has long been a strong advocate for acquisition reform, and the structure of KEI reflects several different acquisition reform ideas he has helped to pioneer. The more flexible MDA acquisition environment permits greater latitude for innovative program managers such as Terry Little to experiment with novel acquisition approaches, including concepts such as EA. Interestingly, however, even Terry Little has backed off on some of the original elements of spiral development as originally conceived in implementing the KEI effort.

Nonetheless, KEI is clearly structured as an EA effort, with the central focus, like other EA programs, on rapid deployment of initial, operationally useful capabilities. An EA strategy is used to mitigate schedule, technological, and cost risk by producing more modest capability blocks in increments, and by focusing, in principle, on more mature technologies. According to senior program managers, the KEI program structure has been derived by asking the following question: What meaningful part of a threat can be addressed with existing industry capabilities and within the required schedule?

Thus, KEI might be characterized as emphasizing schedule as an independent variable (SAIV) as well as CAIV.[24] Thus increment threshold system requirements are driven by schedule realism (what

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[23] As of early 2005, the MDA Director was Air Force Lt Gen Henry A. "Trey" Obering III.

[24] SAIV is a play on words (or acronyms) used by the authors in reference to the well-known acquisition reform concept of the 1990s called CAIV, or cost as an independent variable.

operationally useful capability can be realistically achieved within a reasonably short schedule?) and by cost realism (what operationally useful capability can be realistically achieved within the budgeted resources?).

In addition, program managers have established some fundamental rules, based on past acquisition reform experience, designed to help them achieve the hoped for EA benefits while avoiding the pitfalls of requirements creep, and high life-cycle costs:

- Avoid user pressure to meet the entire threat in one step.
- Treat contractor promises to meet the entire threat with skepticism.
- Emphasize manufacturability and software readiness.

Finally, KEI's focus on evolutionary requirements and capabilities is combined with the radical acquisition reform concept of price-based acquisition (PBA) to maintain contractor focus on cost realism and continuous cost reduction (Lorell, Graser, and Cook, 2005).

KEI Spirals: A Radically Different Approach. The KEI program is notionally divided into four spiral elements that correspond to different launch platforms and different intercept phases of the target missile trajectory:

- Spiral 1: Ground-based mobile boost/ascent-phase interceptor
- Spiral 2: Transition to sea-based interceptor
- Spiral 3: Ground/sea-based midcourse interceptor
- Spiral 4: Space-based interceptor.

The KEI spiral 1 system, which is the only system that had been considered in any detail as of mid-2004, consists of three components: a command, control, battle management, and communications (C2BMC) system, a launcher, and a missile. In December 2003, MDA awarded Northrop Grumman and Raytheon an eight-year, \$4.6 billion development contract. The program office plans to award the winning contractor a firm-fixed-price/incentive-fee contract, with a warranty, for each of the three system components for

Spiral 1. The program office aims at fielding the ground-based mobile interceptor in the 2012–2013 time frame.

In a radical departure from normal DoD practice, KEI's PBA approach means that the unit price for each component will be independent of the quantity produced. As part of the down select, the competing contractors were required to offer an option for a single firm fixed unit price for all units during development, no matter the number that are eventually procured. The approach of combining competition plus the requirement for a single firm fixed price with a warranty emulates commercial market conditions that encourage contractors to focus on price, quality, and manufacturability. The KEI SPO evaluated the initial cost and schedule estimates submitted by the competing contractors (although a Truth in Negotiations Act [TINA] waiver had been received), and adjusted them in order to achieve greater schedule realism.

Like the other programs examined in this chapter, KEI is still at a very early stage of development and design. The spiral program structure is still notional. And in spite of its innovative approach and its flexible acquisition environment, KEI has not been free of controversy. Indeed, in July 2004, at the same time Congress slashed funding for SBR, the Senate proposed cutting nearly 50 percent of the KEI FY 2006 budget request. While the KEI acquisition program generally escaped major public criticism comparable to SBR, many senators expressed deep concerns about the proposed basing mode for the ground-based KEI.[25] The proposed cuts were sustained in the conference report (Ruppe, 2004).

Although KEI has hardly been free of controversy and has suffered significant funding cuts (with more possibly coming in the future), little of the criticism has been directed against its innovative acquisition strategy and its planned use and implementation of EA. Unlike SBR, which Congress explicitly directed to be cancelled as a

[25] The criticism is based on the concern that the KEI ground-based interceptor allegedly must be located unreasonably close to the launch points in the countries of several potential adversaries in order to intercept effectively during the boost phase (see, for example, Selinger, 2004).

formal acquisition program, KEI is expected to be delayed only by funding cuts, while continuing forward as a formal acquisition effort.[26] Therefore, whatever the merits or lack thereof of the program with respect to a ground-based boost-phase interceptor, and whatever its fate, the authors believe useful lessons can still be garnered from the program's overall history through 2004 with respect to implementing EA. To a lesser or greater extent, the same is true of the other four case studies examined here.

Some Lessons Learned from Space Case Studies for EA Implementation

The Need for Additional Up-Front Spending

All the program officials interviewed, particularly those involved in SBR and KEI, emphasized the importance of planning for and obtaining extra up-front spending in large-scale, complex EA programs. This requirement arises from the necessity to map out the complex program structure implied by EA, which includes a series of separate overlapping increments, each requiring the definition of operationally useful threshold and objective requirements; and the additional system engineering and nonrecurring engineering to support the progression of upgrades and technology insertion that takes place within and between increments. Also, additional up-front resources are required to support more extensive and continuously revised evolutionary costing efforts.

Shifting User Feedback Loops to the OT&E Phase

All program managers, particularly those in the SBR and KEI programs, stressed the importance and difficulty of controlling require-

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[26] Some observers anticipate further funding cuts to MDA in 2005. There continue to be advocates for cancellation of KEI outside of DoD, and of course the program could be cancelled in the future. For a typical argument advocating cancellation, see Dinerman (2005). According to press accounts, draft budget documents show an MDA KEI funding request for FY 2005 of $230 million. This compares to an anticipated $1.1 billion FY 2006 request for KEI projected by MDA in its 2004 budget documents (Capaccio, 2005).

ments creep and add-on, particularly in an evolutionary acquisition environment. Initial conceptual versions of EA strategies using spiral development envisioned constantly functioning feedback loops from the user community to fine-tune requirements and make sure that developers produced end products that meet real needs in the field. But actual experience in the early phases of the case study programs described here suggest that uncontrolled feedback in the early concept development stages, particularly on programs with multiple user communities such as SBR, can lead to a counterproductive piling up of sometimes mutually inconsistent requirements, concepts, and technologies.

The KEI program managers particularly stressed the importance of restricting the feedback loop process to the OT&E phase when actual hardware exists and can be evaluated. In the view of the KEI program managers, constant uncontrolled early feedback from the user undermines the fundamental benefits of EA, because the user communities tend to press for the full achievement of maximum objective requirements from the beginning, thus pushing programs toward more traditional single-step-to-capability program structures. This problem is exacerbated when multiple user communities are involved, as in the case of SBR.

"Logistics Takes It in the Shorts"

In the colorful phrase of one program manager, it is crucial for EA program managers to recognize and plan for the fact that "logistics takes it in the shorts" in EA programs. What is meant by this colorful phrase is that EA greatly complicates logistics planning (and life-cycle cost analysis) by leading to a proliferation of different system configurations as the system evolves through its increments or spirals. The best approach to dealing with this challenge, in the view of several program managers, is to plan from the beginning to back-fit earlier variants to bring them up to the standard of the latest configurations, or merely to replace old variants with the current versions. The KEI program manager suggests a "blast down" solution for old variants, where the earlier versions are consumed through use as test vehicles for later stages of the program. Whatever the approach, budget plan-

ners, cost analysts, and logistics planners must be prepared to anticipate and plan for the additional complexities and costs that will be incurred through the use of EA by the fielding of multiple versions and configurations of the same system.

Focus on Capability Objectives, Not Traditional Requirements

In the view of several program managers, EA provides a structure and a process to achieve the long-sought acquisition reform objective of focusing on capability objectives. According to this view, programs should seek to develop and acquire a well-defined, needed, and realistic mission capability rather than focusing on meeting detailed technical requirements established at program inception. Such an approach—which gives the SPO and the contractor greater flexibility to seek innovative technical and operational solutions to help meet well-defined mission and capability requirements—can, in principle, be facilitated by EA.

As programs move toward more rigidly defined and narrow technical requirements definitions and key performance parameters (KPPs),[27] they tend to migrate toward the more traditional single-step-to-capability approach. In the view of the KEI program managers, the SPO should emphasize mission assurance (as stressed in the Young Panel findings) and schedule realism above any rigid adherence to narrow technical requirements. Unfortunately, existing regulatory and political pressures tend to push programs strongly in the latter direction, according to the SBR program managers and others.

Ironically, establishment of KPPs was a crucial element of some of the early acquisition reform pilot programs in the early 1990s, such as JDAM and JASSM. The point then was to focus the program office and the contractors on a small set of broad but critical performance measures that would orient the programs toward capability ob-

[27] KPPs were introduced during the burst of acquisition reform implemented by DoD in the late 1990s. They were part of the move away from detailed technical military specifications in ORDs toward requirements defined in performance terms. KPPs are nonnegotiable minimum requirements, which cannot be traded off against cost or schedule, and that are usually stated in performance capability terms rather than in technical terms.

jectives and away from detailed technical requirements and specifications dictated by the government. Both Terry Little at the KEI program office, who helped develop the KPP concept on the JDAM and JASSM programs, and the SBR program managers are vigorously opposed to the KPP concept now. This is because, since the 1990s, the use of KPPs has drifted away from the original focus on broad mission capabilities and toward the old concept of detailed technical performance requirements. Thus, program officials at SBR and elsewhere complained that highly specific and narrow KPPs are established early in the program and then rigidly adhered to, thus stifling creative solutions that emerge later and limiting the ability of program managers to trade off small amounts of capability in one area for large returns in another area, or in cost or schedule reduction.

Evolutionary Costing Works and Is Widely Accepted on EA Programs

Nearly all the cost analysts interviewed who were involved in or familiar with these case studies expressed confidence in the use of an evolutionary costing approach on EA programs. Program managers noted that evolutionary costing is the only feasible and realistic approach to use on EA programs, especially those that employ the spiral development process. Evolutionary costing requires that the cost analysts work closely with the contractors and the government technical team to track the design and the technologies as they evolve. One approach that is popular is to develop cooperatively a joint cost model with the contractor, based on mutually agreed upon methodologies, baseline assumptions, and cost factors, that facilitates the constant updating of the cost estimates as the design evolves and new information and data are input into the cost model.[28] The inputs to the government model may not be the same as the contractor's model; however, joint models tend to make the discussion and reconciliation of the cost estimates much more effective.

In virtually every case examined, the cost analysts overwhelmingly focused their efforts on the initial increment or spiral, since

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[28] This approach has been successfully used on other types of programs, including the C-17 Globemaster III airlifter, and the T-6A Texan primary trainer programs.

these were the only elements of the overall programs that had been fleshed out in sufficient technical detail to permit credible cost estimating efforts. In most of the programs examined, the cost estimates for follow-on increments or spirals merely reflected the funding allocations planned in the Future Years Defense Plan (FYDP). As one program director noted, detailed cost estimating on any of these programs beyond the first increment is "pure speculation."

This, of course, also represents the potential political shortcoming of evolutionary costing. Such an approach leaves programs open to concerns in Congress and elsewhere over contractor or service buy in, especially in the wake of such troubled programs as SBIRS-High. In the view of senior acquisition managers at SBR, such concerns drove cost analysts away from using an evolutionary costing approach, and eventually led to an unfair penalization of the program that was rigorously attempting to implement truth in costing. Whether or not this generalization is valid specifically for SBR is irrelevant here. The point made by many program managers that evolutionary costing raises the potential for political criticism is probably justified.

Having raised some of the more widely recognized lessons, issues, and concerns regarding EA that emerged from specific case studies, the monograph now turns to a brief summary review of the overall findings of the study.

CHAPTER THREE

Summary Overview and Concluding Observations

Introduction

Many of the observations and policy recommendations mentioned in this chapter are applicable to all acquisition programs, whether using the EA process or not. However, it is the authors' view based on both case studies and other independent assessments that EA tends to promote certain conditions that raise issues for acquisition managers and cost analysts that, while not unique to EA programs, tend to be more prominent in such programs. More is said on this at the end of this chapter. This brief chapter summarizes and reviews the authors' principle findings on evolutionary acquisition based on a reading of the relevant literature, examination of five major space acquisition case studies, and interviews with numerous DoD, product center, program office, industry, and other relevant acquisition managers and cost analysts. This chapter is divided into two sections. The first presents the authors' findings and insights that are relevant primarily to acquisition managers. The second focuses on topics of special interest to cost analysts.

Summary of Acquisition Management Findings

The new DoD guidance on EA permits greater flexibility, but does not eliminate conceptual and definitional ambiguity. A wide

consensus emerged among officials interviewed that the new DoD 5000.1/2 and NSSAP 03-01 guidance documents on structuring acquisition programs in general and evolutionary acquisition programs in particular permit far more flexibility in program approach and implementation than was typical in the past. Most program managers considered this a highly welcome development, permitting them to tailor program structures and approaches more proactively to meet the unique circumstances of specific programs more effectively.

One of the main reasons senior OSD leadership issued the new DoD 5000 acquisition policy guidance in May 2003 was the continuing confusion and ambiguity regarding EA definitions and terminology that resulted from the initial, formal promulgation of EA as the preferred acquisition approach in October 2000. However, the authors' review of the relevant published literature, five case studies, and extensive interviews with acquisition officials, suggest that there are still considerable variations and inconsistencies among programs, even at the same product center, in the use of EA-related terminologies and the application of EA concepts. For example, some programs label their EA segments "increments," and some label them "spirals," often apparently with little regard for the significant distinctions laid out in new DoD 5000 guidance between the spiral development process and the incremental development process. Other factors, such as the use and importance of feedback loops, which are of great importance theoretically in the implementation of EA, vary considerably from program to program. As discussed later, this lack of consistency may be more a function of some major structural and institutional challenges confronting implementation of EA in certain types of programs, rather than confusion or ambiguity regarding the definition of the terms.

Appropriate structuring of EA phases with operationally useful threshold requirements and mapping the path to overall objective capability are major challenges. Developing the structure, phasing, and content of the specific increments for EA programs is proving to be a major challenge. Nearly all the programs examined focused overwhelmingly on the initial program spiral or increment. Almost all the programs were struggling with defining acceptable

threshold requirements and capabilities for operationally useful systems for the initial EA phase, as well as for follow-on phases. Objective end requirements, and sometimes even objective end capabilities for the overall program, often remained vague and highly speculative.

Often much uncertainty existed even for the initial Phase 1 increment or spiral. The first or initial phases for virtually all the programs examined appear to be evolving toward de facto stand-alone programs. In many of the programs, acquisition managers experienced strong pressure from user communities to maximize capability targets for the initial segment, thus pushing the first phase increasingly toward something approaching a traditional single-step-to-capability program with internal block upgrades.

The use of the spiral development process on major hardware acquisition programs raises serious challenges for program managers in the current acquisition environment. The very uncertainties that provide acquisition managers with valuable flexibility necessary to gain the expected benefits from EA through spiral development also raise considerable challenges for managers in the existing acquisition environment. This is particularly true, as discussed in the previous chapter, in large, high-profile programs such as SBR, the original Big RAIDRS, and, to a lesser extent, KEI. It is not always politically feasible to expect Congress to fully support potentially very costly programs based on new and possibly immature technologies and concepts—programs that may not be as highly structured as traditional programs, and that do not have precise and detailed concepts of the first phase threshold system requirements and capabilities, much less the final end-phase objective system. This is particularly true of large, transformational space programs, given the recent unhappy experience with SBIRS High and other earlier efforts.

Acquisition managers of such programs report that they are subjected to very strong pressure from the requirements and cost analysis community to provide far more detail about the end stages of the program than they believe is feasible under the spiral approach. The whole spiral concept assumes that the major components of the program emerge and are defined through experimentation as the program progresses. Such a concept may be too open-ended to be politi-

cally practical in the overheated environment of defense budget politics. Useful flexibility and prudent incrementalism to one observer may appear to another observer to be a devious attempt to buy-in.

The authors found that many of the large, higher-profile programs examined, such as SBR, GPS III, and Big RAIDRS, were evolving away from the use of the spiral development process. These programs were increasingly focused on clearly structuring the initial increment in considerable detail, and in nailing down and finalizing both threshold and objective requirements for the first increment. In the process of doing spiral development (SD), some, such as SBR, came under great budgetary pressure from Congress, and were restructured or evolved toward something approaching technology demonstration programs or more traditional single-step-to-capability programs with stepped block upgrades.

It is no wonder, then, that in part due to the experiences of SBR and other programs, senior Air Force officials and acquisition managers appear to have steadily retreated from openly advocating the spiral development process and moved increasingly toward incremental development. Yet the risk in moving toward incremental development is that programs using such an approach may easily transform into de facto traditional single-step-to-capability programs, perhaps with internal block upgrades, that are indistinguishable from the old acquisition approaches.

Based on these case studies, it appears that a spiral development approach is more politically practical on smaller, more modest, lower-profile programs such as the current RAIDRS and, to a lesser extent, SBSS. With a smaller likelihood of being subjected to severe public scrutiny and criticism over the lack of precise objective program end requirements, these programs have greater freedom to pursue a more flexible approach to evolving requirements over time. Yet even in these programs, the tendency has clearly been to move toward more precise and early definition of final requirements, in part due to pressures from the cost estimating community and the need to meet a variety of regulatory oversight and reporting requirements.

Therefore, the authors believe that evolutionary acquisition using the preferred approach of spiral development, as laid out in the

most recent DoD 5000 and NSSAP 03-01 guidance, may be difficult to implement in the current political and acquisition environment on major DoD space programs, and possibly on other large-scale DoD hardware acquisition programs.[1] At best, EA using spiral development may be one useful tool that can be used in some limited circumstances on software programs, on smaller-scale hardware programs, or perhaps on programs such as KEI that operate outside the traditional acquisition framework.

Summary of Cost Management Findings

EA poses few insurmountable challenges to cost analysts. Compared to other traditional program approaches, EA requires more extensive up-front and continuing participation of the cost analysis community as the program evolves. Based on the authors' extensive interviews with senior cost analysts at the Air Force Cost Analysis Agency (AFCAA), the CAIG, and SMC, the authors have concluded that while EA substantially increases the up-front and ongoing workload for cost analysts, it in and of itself raises few insurmountable problems or obstacles for cost analysts. The most challenging issue is having access to realistic and independent technical assessment of the program baseline assumptions. NSSAP 03-01 in particular places a very heavy emphasis on early, high-quality, and multiple independent cost analyses and other forms of program review for all major space programs. This results in a considerable increase in workload for cost analysts.

There was a consensus among the program managers and cost analysts interviewed that the only sensible approach to dealing with EA programs was to adopt what amounted to an evolutionary costing strategy to mimic the evolutionary nature of the development of the system. As the system design and technology evolve and mature

[1] A comprehensive analysis of the effects of EA on nonspace MDAPs is necessary to make a more definitive statement.

through various spirals or increments, so must the cost estimates go through cycles of increasing refinement and fidelity.

Another key strategy for coping with cost estimating on EA programs is to focus heavily on the initial spiral or increment, whose specific content is generally far better defined than later spirals or increments. Typically, follow-on increments are nominally costed to the Future Years Defense Plan, and estimates are revised as requirements are refined. As one program manager noted, costing future increments or spirals on EA programs is often an exercise in "pure speculation." While cost analysts appear to be having no problem adjusting to this approach, evolutionary costing can increase program exposure to political allegations of buy-in or lack of full disclosure.

Concerns linger about the ability of EA programs to generate credible early program LCC estimates when future requirements and technologies remain so uncertain. Overall, most cost analysts interviewed expressed generally positive views about EA. Nonetheless, lingering concerns did surface during interviews regarding a variety of cost issues associated with EA:[2]

1. Committing the USAF to large, costly programs before the full cost implications of the program are well understood
2. Accurately assessing total program LCC, support costs, and retrofit costs based on sound and independent technical assessment of the program baseline
3. Adequately budgeting for the potentially high variability of cost outcomes arising from the high degree of uncertainty surrounding inputs to cost models.
4. Accurately accounting for the potential cost implications of requirements creep arising from multiple users and planned insertion of technologies of uncertain future maturity.

The cost analysts interviewed did not view any of these potential challenges as show stoppers. Nonetheless, there was recognition—at

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[2] Concerns similar to those listed here have been expressed in many quarters. For example, see Levin (2003).

least among some of those interviewed—that EA would increase the cost analysts' initial workload and require substantial interface with the engineers and the contractor. In addition, some of these issues could pose serious political problems for program managers. In addition, all the programs surveyed were in such an early stage that several of these challenges were only latent.

For example, the challenge of estimating the program cost implications for logistics support of multiple different versions of the same system arising from different increments or spirals (none of which can be predicted accurately at program inception), and the probable need to retrofit or upgrade earlier versions to bring them up to the standard of the more recent variants later in the program, were recognized as potentially significant cost estimating issues.

Clearly the experience of the SBR and KEI programs demonstrate that the use of EA, especially using the spiral development process, greatly increases exposure to the possibility of criticism from Congress and other outside observers, at least in situations where technologies may be new and immature, or where disagreement exists over CONOPS and mission effectiveness.

Nonetheless, a strong consensus emerged from these interviews with cost analysts that EA is an important and useful tool that provides program managers with increased flexibility, and that can be accommodated adequately by the cost community through the use of evolutionary costing.

Applicability of EA Findings from Space Programs to Other DoD Acquisition Programs

As discussed in Chapter One, space programs differ from other types of DoD defense acquisition programs. This raises the legitimate question of how relevant EA findings drawn from space program case studies are to other types of defense acquisition programs. In Chapter One the authors examined the major differences between DoD space and other types of programs and made some comparisons between the formal acquisition policy documents governing acquisition of the

two categories of programs. In it, the authors determined that this information was inconclusive regarding the applicability of EA findings based on space programs to other types of programs.

In this subsection, the authors examine information that appears to shed more light on the issue: other systematic studies of EA implementation on different types of programs, and past and ongoing RAND research on several UAV programs that many in DoD have long considered key test cases for the EA strategy.

Other Research Findings

The most extensive published study of which the authors are aware that examines actual EA implementation issues based on real-world experience with nonspace programs is a master's thesis written by an Air Force officer, Gary L. Wellman, in the Acquisition Management Program in the Department of Systems and Engineering Management at the Air Force Institute of Technology, Air University, Dayton, Ohio (Wellman, 2003). Wellman conducted structured group discussions with civilian and military contracting officers located at three different Air Force product centers: Air Armament Center (AAC), Eglin Air Force Base, Fla.; Aeronautical Systems Center (ASC), Wright-Patterson Air Force Base, Ohio; and Electronic Systems Center (ESC), Hanscom Air Force Base, Mass. While this study focused exclusively on SMC plus MDA, Wellman's study examined EA issues at the other three principal Air Force product centers. Wellman focused primarily on contracting issues, and interviewed only contracting professionals who had experience with EA programs. However, his larger goal was "to identify potential roadblocks to implementation of Evolutionary Acquisition strategies," and identifying approaches that "may counter the identified challenges" (Wellman, 2003, p. viii).

Wellman undertook his study because, while "EA has been mandated as the acquisition strategy for all ACAT I programs, . . . [n]o firm contracting guidance has been provided on how to accomplish this task either at the DoD or the individual service level" (Wellman, 2003, p. 6). The authors found that this situation existed across the board on most EA implementation issues, and had con-

tributed to the lack of consistency and confusion regarding the implementation of the policy.

Wellman's findings from the three product centers can be summarized as follows:

1. The "increment definition process" is identified as a serious area of "concern," while "unknown capabilities" in future increments "pose their own set of unique challenges in the refinement of future increments" (Wellman, 2003, p. 69). More specifically, interviewees identified a variety of challenges in this area: establishing a process and an approach to defining each increment; defining future increments when capabilities are unknown; determining who should be in charge of the process; and other issues. Interviewees stressed that increments and the end capabilities and systems should be well defined at the very beginning of an increment, but often are not (Wellman, 2003, pp. 68–69).
2. Serious constraints are identified that inhibit the successful implementation of EA strategies. These include "mindset constraints" (under which the author includes "lack of specific guidance" from management); "partition constraints" (in which the author apparently includes regulatory issues); and "brick wall constraints," which are the most serious political, statutory, and regulatory constraints.[3] By far the most important of these is "the government funding process." Here the most significant constraints were "the affordability of the increments," the "availability and timing of funds," and the "color of money" (Wellman, 2003, p. 45). Other difficult areas included a range of statutory and regulatory roadblocks, such as the Competition in Contracting Act and the Small Business Act. Wellman concludes that "in order to effectively implement EA, the Government must ensure that its practices and processes, to include regulatory guidance, reflect the intent of the preference for EA strategies" (Wellman, 2003, p. 74).

[3] "Brick wall" constraints are ominously defined as "those that cannot be overcome and are considered unalterable" (Wellman, 2003, p. 43).

While Wellman is primarily concerned with the minutiae of contracting, and spends most of his efforts at examining detailed contracting workarounds for specific practical contracting issues, his broader conclusions seem to be consistent with the authors' findings. Most importantly, his respondents identified the key challenge of the "increment identification process," and the problem of defining future increments with unknown capabilities. This was perhaps the central problem area for most of the space programs examined here, particularly SBR, RAIDRS, and GPS III.

The second publicly available study is perhaps even more relevant to this research, and strongly confirms many of the authors' findings from space programs. This is a case study conducted by Walt Pingel, a cost analyst at the Global Hawk UAV Program Office at ASC who has worked on this program from its earliest phases, as well as other UAV programs such as DarkStar. The case study is specifically aimed at evaluating the implications of EA for cost analysts. The case study findings were presented to the DoD Cost Analysis Symposium in January 2003 (Pingel, 2003).

Global Hawk is a complex program with many unique and unusual program attributes. This is not the place for a detailed review of this program. Nonetheless, as noted in Chapter One, Pingel correctly argues that Global Hawk has historically been viewed as a principal test case for the efficacy of EA.[4] Therefore, it seems appropriate to summarize his key findings for the purpose of demonstrating their similarity to the authors' findings on space programs, rather than to make a judgment of overall performance of the Global Hawk program. Pingel's findings can be summarized as follows:

1. "[The] spiral development process engenders a very high amount of concurrency between program phases. . . . A high degree of co-

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[4] For another example of the use of Global Hawk as a key DoD case study, see Johnson and Johnson (2002). A current research project undertaken by the National Academies titled "Test Strategies for Evolutionary Defense Acquisition" has looked at Global Hawk as a key case study, along with JASSM, JSOW, Small Diameter Bomb, and FCS. Of these cases, only Global Hawk is a major system platform program that is well advanced in the procurement cycle, and is already in production.

ordination is required at all times to ensure the program strategy does not become disconnected between acquisition phases." Pingel (2003, p. 12) then notes, "the program estimator is one of the people who pays a high price for disconnected, obtuse, or conflicting program strategy and assumptions."

2. The Global Hawk program using EA has been characterized by "severe swings in force structure, acquisition strategy, schedule, and operational concept." This situation has "meant seismic shifts in the nature and composition of the program estimate."[5]
3. "The concept of spiral development is one of many increments, all being independently managed. In reality however, there are certain activities that are Level of Effort in nature, that. . . continue across multiple spirals and service a host of spiral increments. So the estimator faces the challenge of not only estimating each independent development activity, but the 'overlay structure' surrounding those activities" (Pingel, 2003, p. 14).
4. A key "problem is that many of the [spiral increments] are poorly defined." While this problem may also arise on traditional programs, spiral development adds "another wrinkle. . . . That wrinkle is the fact that the user, through continuous feedback, constantly reprioritizes the scope and content of the spirals, usually future spirals, but sometimes even for increments on contract." As a result, "the estimator constantly has to adjust the increment estimates that are impacted by the change, and must understand the synergies between cost elements so that overlay activities. . . can be adjusted accordingly" (Pingel, 2003, p. 14).
5. "Because of the rate of change in a spiral program, the regulatory review system struggles to keep up with changes in both program

[5] Pingel (2003, p. 13). At least some of this is due to the urgent post-9/11 requirements to field UAV capabilities rapidly in Afghanistan and Iraq. DoD deployed prototype versions of both Global Hawk and Predator that had not been fully tested to active theaters of operations. These actions caused major acquisition program disruptions, and significantly increased the flow-back of requirements and technical changes based on field experience. Nonetheless, both contractor and government officials strongly believe that EA and spiral development approaches on their own inherently contribute to program flux and instabilities, particularly in the area of requirements change and growth.

content and direction. Our current regulatory system is simply not designed to deal with a program that changes constantly and swiftly. . . . Valuable, limited resources and time are spent re-viewing and re-reviewing previous analysis, re-educating management, and re-justifying program direction instead of performing current data collection, analysis, as well as the general business of running a program." While Pingel notes that "many programs have these problems," he insists that "the conflict between the nature and speed of a spiral development versus our current regulatory environment" makes the problem far worse in an EA program (Pingel, 2003, p. 11).

6. And finally, Pingel concludes that "if there is anything you should take away as a lesson learned it's that logistics, retrofit, and integration activities' costs are very difficult to ascertain, and have the potential of becoming much more expensive than historical data would indicate" (Pingel, 2003, p. 17).

Ongoing RAND Research on UAVs

As mentioned in Chapter One, RAND has published several studies in the past on the Global Hawk and Predator acquisition programs, and is currently conducting ongoing research on these and other UAV programs. While that work is still underway, is focusing on other issues, and has not yet generated final research results, the information RAND has collected through the summer of 2005 on the EA strategies used on Global Hawk and other UAV programs is consistent with the findings of the Pingel study.

For the Global Hawk program, RAND has conducted extensive interviews with program management and cost professionals representing both the Air Force Program Office and the prime contractor, as well as other entities. Many of the RAND interim findings seem to confirm Pingel's observations. Some of the key points that have emerged to date relating to the implementation of the EA strategy include the following:

1. Program managers and cost analysts have faced major challenges caused by the constant changes in requirements, operational con-

cepts, and technical specifications. It is the consensus view among both prime contractor and government personnel that these challenges are made much more daunting by the early fielding and constant requirements feedback process promoted by EA. To paraphrase one contractor official, the EA process provides an irresistible opportunity and temptation for the user to constantly change, add, and fine-tune requirements and operational concepts. While this is not necessarily a bad thing, especially from the user's perspective, it has created continuous change and uncertainty in all aspects of program management and cost analysis. According to the Global Hawk prime contractor, the program has experienced unprecedented levels of "requirements churn." In calendar year 2004 alone, the contractor experienced on the order of 200 contract actions, contributing significantly to program cost growth. In addition, the large numbers of contract actions placed an unusually high workload burden on both the contractor's engineering staff and the cost analysts, and diverted them from focusing on core aspects of the program. The whole requirements and technical change process has proven extremely difficult to discipline and control.

2. Defining the precise technical content of specific spirals or increments and costing them appropriately has posed challenges. The ad hoc transfer of specific subelements and tasks from one spiral to another has complicated this, as program goals, funding, and technology maturity assessments constantly change. Another problem has been allocating overhead and other aspects of the "overlay structure" among different spirals. To paraphrase one contracting official, EA, with its multiple, overlapping increments, opens the door to much more complexity and change than is common in typical traditional programs.
3. A consensus view appears to exist among Global Hawk program office acquisition managers and cost analysts that EA and spiral development do result in fielding operationally useful systems much sooner than the traditional approach, but at a much higher cost. These officials argue that a cost-effective program requires stable requirements, system configuration, and quantities, and

> adequate funding. In their view, EA and spiral development approaches promote constant flux in all these program attributes, leading inevitably to cost estimating difficulties and cost growth. The key lesson learned from Global Hawk, according to one official, is that the only way to implement spiral development effectively was to provide unlimited funding to cover the unending changes. Otherwise, in the colorful words of another official, spiral development tends to end up becoming "spiral death."

Based on this quick review of two other independent studies of the implementation of EA strategies on nonspace programs, as well as ongoing RAND research on Global Hawk and other UAVs, the authors conclude that the findings reported in this monograph based on space program case studies are reasonably robust, and are largely applicable to other major DoD defense acquisition programs. The authors find that all the cases reviewed, including those in the Wellman study, which covered a wide range of programs at ASC, AAC, and ESC; the Pingel case study of Global Hawk; and RAND's own past and ongoing research on Global Hawk and other UAVs, have found with remarkable consistency that the real-world application of EA approaches raises serious challenges for program managers and cost analysts in the same set of areas. While these challenges are not unique to programs using an EA approach, they appear to be more formidable in EA programs. These areas include the following:

- Requirements and technology churn
- Increment or spiral definition and content
- Program complexity and concurrency
- Logistics planning and complexity
- Funding coordination for increments
- Regulatory environment and oversight requirements.

To be fully confident in the robustness of these findings, however, the authors believe that in the future, extensive additional case study analysis of nonspace EA programs is fully warranted.

EA Challenges: A Flawed Approach, or Flawed Implementation?

Based on the case studies and on other published assessments, there appears to be little doubt that EA strategies, whatever benefits they may produce, have resulted in significant challenges for acquisition managers and cost analysts. It is legitimate to question, however, whether these challenges arise inherently from the strategy itself, or rather are more a function of incomplete or improper implementation of the strategy.

While a precise, quantitative answer to this question is not possible, it is the authors' sense that the challenges posed by EA strategies arise from a combination of both causes.

Probably the single most daunting challenges posed by EA are controlling requirements and technology churn, and stabilization of the definition and content of increments. Based on the review in Chapter One of the new DoDI 5000.2 documents and the new NSSAP 03-01, it is clear that the authors of these documents were extremely sensitive to these challenges and explicitly restructured the proscribed acquisition process in order to try to ensure that requirements were well defined, selected technologies were mature, and the structure of a given increment was well thought out prior to formal program initiation and passage through Milestone or KDP B.

In the real world, however, it has proven difficult to implement this carefully planned structure. The reason in part seems to be that the EA approach, with its strong emphasis on user feedback, and its flexible approach to final requirements, inherently encourages strong pressures from user communities to continue changing requirements and redefining increments throughout the acquisition process. This is true in the early phases of space programs examined such as SBR, where acquisition managers were bedeviled from the start, and without let-up, by constantly shifting requirements and capabilities demands from user communities. Global Hawk, and, to a lesser extent Predator, which are totally different kinds of programs, and which are in a far more advanced stage of the acquisition process, have both experienced the same kind of unusually high degrees of requirements

and technology churn. Thus, although safeguards against these problems were carefully written into the new acquisition regulations, the EA concept itself seems to promote the uncertainties and churn that cause the challenges for acquisition managers and cost analysts.

Increased program complexity was identified by all interviewees in the RAND case studies, as well in other independent published studies, as an important challenge posed by EA strategies. There is no question that increased program complexity is an inherent attribute of the EA approach. This is because EA envisions multiple increments, all of which are treated in a management sense as quasi-separate programs, with their own milestone reviews, oversight documentation, and so forth. This complexity is increased by the tendency to move content around from one increment to another, a tendency that appears common on both space programs in their early phases and other types of programs such as Global Hawk that are far more advanced in the acquisition process.

Given the challenges posed by the difficulty in defining increments, the constant requirements feedback and churn, and the difficulties encountered in structuring and defining the content of specific increments or spirals, it is not surprising that planning funding for increments has also proven to be a significant challenge inherent to the EA approach.

Finally, there is little doubt that the overall acquisition regulatory and oversight environment affects the ability to implement EA in the form initially envisioned by its original advocates. The extent to which the challenges that have arisen in EA programs are caused by the traditional acquisition regulatory environment is unclear. The new DoDI 5000.2 and NSSAP 03-01 greatly increase the flexibility available to program managers. On the other hand, a significant body of regulatory and statutory requirements based on more traditional approaches still exists. As just one example, the requirement to develop full and accurate LCC estimates in the early stages of the acquisition process is very difficult to achieve in an EA program using a spiral approach, and indeed is not in line with the basic philosophy underlying spiral development.

Finally, there is no question but that the EA strategies inherently complicate logistics planning and cost estimating. By focusing on space programs, this study may have underemphasized this challenge. The indications from ongoing studies of Global Hawk, Predator, and other UAVs using spiral approaches suggest that detailed logistics planning and accurate logistics cost estimating are inherently complicated by the use of EA, because this approach produces so many variants of the basic system.

Therefore, for the most part, it appears that most, but not all, of the significant challenges posed by EA to the acquisition and cost analysis communities are inherent in the process itself. It does not follow that therefore the process of evolutionary acquisition is inherently flawed and should be rejected. Indeed, it could be argued that from the perspective of the warfighter, EA represents a significant improvement over past acquisition approaches. And of course the acquisition community exists only to serve the warfighter. Nonetheless, program managers and cost estimators need to anticipate and be prepared to cope with the increased challenges posed by EA when it is selected as the core acquisition strategy for a major program. This is because the acquisition community is also responsible to the taxpayer and must realistically adapt to the inevitable political realities within which the acquisition process operates.

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